Smart public transportation: A future framework for sustainable new cities (Case study Greater Cairo)

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Abstract. In the context of the tremendous progress in information technology in all spheres of life, it is necessary to adopt more intelligence solutions to increase the quality of life and achieve sustainable cities. Currently, without a doubt, we have the ability to make all city services accessible to everybody. Transportation and mobility systems are critical components of sustainable city development. Therefore, the scientific literature on the technological systems employed in transportation systems and their primary uses is extensive, outlining their application to improving people's quality of life through promoting a sustainable environment. Recently. There is a new generation of ITS (intelligence transportation system) resulting from the encouragement of related public policy that has been deeply integrated with new infrastructure and new technologies for improving the quality of life. The new generation of ITS technology and urban analysis and planning technology can not only meet the current problems of the coordinated development of the public transportation system and big cities like Cairo, but also meet the needs of the city's future development in advance. This paper will discuss the transformation of intelligent public transportation, the opportunities, and applications, using technologies, and implementation in various urban areas using a case study of China's smart transportation. Additionally, propose a future framework for sustainable transportation in new cities and the feasibility of implementing them in Egypt's new cities. Highlight the actions and outcomes of integrating technologies, as well as their environmental, urban, economic, and social impacts. In order to develop and increase the quality of life in the cities of Egypt and the developing world in order to achieve sustainability goals.

Keywords: Smart Transportation, sustainable city, Transport in GC, ITC

1. Introduction

In developing countries, the conventional methodology for handling the transportation congestion issue has been, for a long time, to include more open transport centres, incorporating prepared stations, quick travel stations, transport stops, etc., and constructing new ones, in this way permitting better traffic conditions, review [1][2]. This approach isn't the better solution, in terms of retaining a colossal sum of rare monetary and land resources, causing environmental intrusion, and generally increasing the environmental and safety hazards [3]. For example, greater Cairo (GC) is experiencing severe traffic congestion, which is resulting in delays, a decline in safety records, and significant environmental costs in terms of pollution and energy usage [4]. For a comprehensive examination of GC's urban transportation issues [5]. The tendency has been to adopt a significant change in thinking. While many countries' resources are becoming scarce, the proclivity has been to embrace data and communication innovation that enables the most effective use of techniques and applications. The notion of sustainability is evolving via more participation, as regional sustainability is defined as achieving a balance of social, economic, and environmental sustainability. At the city level, sustainability is determined by the extent to which cities are adaptable to changing requirements and the capacity of its elements and activities to adapt to the numerous changes in society through time [6]. For a long period
of time, countries around the world have aimed to attain sustained economic development. Sustainability displays a commitment to reducing resource and material use in order to ensure the survival of future generations. Transportation in metropolitan areas is critical for encouraging economic development on a sustained future. Therefore, in advanced countries, urban smart transportation is moving towards better electrification, automation, and connectivity rapidly. At the same time, as the market for personalized, diversified, and high-quality travel services continues to expand, the innovation process of urban public transport service models is also accelerating [3]. With online appointments, sharing, and customization, new types of bus services with characteristics are emerging. In addition, as new technologies such as big data analysis, BIM (Building Information Modeling), and GIS (Geographic Information System) are applied to the planning and construction of major cities [7] such as China, which makes it possible to improve, break through and innovate the classic theories and methods of urban public transport planning, design and operation management [8][9]. The case study and comparative study of typical cities in China and Egypt can also be used for the development of the urban public transport industry and equipment systems in China. Manufacturing and technological applications increase the value of popularization and have a radiation effect. The study was conducted as part of a series of studies targeting the integration of smart technologies that provide various solutions able to solve our challenges in Egypt, especially those related to development and increasing the quality of life in the cities of Egypt and the developing world in order to achieve sustainability goals. The series of studies was conducted in collaboration with the CHI Institute and Southwest Jiaotong University with STIFA. The research is part of the author’s participation in the

2. Literature review

2.1. Public Transportation background in Egypt

According to the World Bank statistical analysis, The Great Cairo has a huge population, more than a fifth of Egypt's population [10]. Along with being one of the world's largest cities, it faces the same environmental, economic, and urban constraints as many other major cities in developing countries [4]. The Egyptian government has been building new cities to accommodate the increasing population. Most of the new cities are not covered by a public transportation system. Therefore, a lot of citizens move to their work using their own cars or informal public transportation, which leads to traffic congestion. Traffic congestion results in a lot of wasted time, which reduces the productivity of the employees, increases fuel consumption, reduces the efficiency of the vehicles, and increases air pollution. Total daily visits climbed from 5.6 million in 1971 to 21.6 million in 2001, according to the Developing Research and Technology Planning Centre and Cairo University, and are expected to exceed 30 million in 2022 (DRTPC 2009). On the other hand, the shortage of buses means it is hard for low-income citizens with no cars to decide to move to these new areas, which affects the government's efforts to relocate citizens to new districts [11]. Furthermore, there is no way for citizens to know which buses are available in their areas and their schedules without waiting for a long time and with no guarantee of finding a suitable ride [12][13]. And if the citizens find the buses, the heavy capacity inside the buses increases the probability of infections of the citizens with viruses like COVID 19. Furthermore, public transportation providers do not have strong incentives to increase buses and rides in new areas because they are concerned about the financial outcome. This study proposes a future framework for a smart transportation system in order to address the above identified issues.

2.2. New cities of GC: the challenges and opportunities

The new cities planned to provide housing and employment opportunities for the crowded population of Cairo are attractions for the population, in order to ease the pressure on the larger Cairo region and to try to obtain integrated urban communities [14]. This resulted in the establishment of New Cairo, Sheikh Zayed and 6th October, furthermore the present construction of the New Capital. Cairo's population has more than doubled in the previous 40 years and is predicted to do so again in the next 40. The government supplies the roads and infrastructure for these new communities. However, because
its people work in other areas of the metropolitan region, these new projects place additional strain on
the city's transportation infrastructure, increasing transportation expenses [3] as shown in figure 1.
Currently, with population growth in new cities, and transportation networks and infrastructure have
trailed behind demand growth, resulting in service expansion being constrained. As a means of public
transportation in Egypt, bus services serve customers with a comprehensive network that spans the
governorate [15]. The CTA is responsible for organizing, management, and operation, as well as for
supervising twenty-two private companies that own and manage concession-line minibus services.
Regardless, the network is underfunded, leading in ageing fleets, congestion, and decreased service
frequency. This substandard service pales in comparison to the advantages of shared taxi services, which
provide customized and flexible stops. Table 1 explains the key issues and actions by the Egyptian
government for improving the transportation sector in new cities of GC. On the other hand, despite all
the challenges that have been mentioned, there is potential for new cities to find and apply solutions
through which they can become sustainable cities, such as the significant urban growth occurring in
GC's new metropolis, The emergence and variety of urban planning and design initiatives to the degree
that they need studies, Spending on development projects. Furthermore, urban design has considerable
economic potential. Using researchers' potential in a city where the new cities are a vast area for
integrated studies is a good idea. By specialized bodies, promotion and facilitation of all disciplines of
studies.

![Figure 1](image1.png)

**Figure 1** the relation between the new cities of GC and development hubs. Source: [14].

| Government challenges | Government actions at last 10 years | Reference |
|-----------------------|-----------------------------------|-----------|
| Congestion exacerbated inadequate public transportation. | Natural gas conversion of public-sector cars. | [4]       |
| A huge cost in terms of higher fuel usage and commuting time lost. | The effort to replace ageing taxicabs. | [5]       |
| High accident rate. | The Transportation Committee of Parliament recommended a new traffic legislation with the goal of increasing traffic safety and reducing road accidents. | [16] |
| A huge cost in terms of higher fuel usage and commuting time lost. | | [17] |
| Pollution of the environment (air, noise, etc.) | | [3] |
| | | [18] |
| | | [17] |
| | | [19] |
| | | [15] |
• Weaknesses and dispersion of institutions.
• Financial arrangements that are insufficient.
• Private cars, and their percentages are increasing.
• The public transportation network does not cover subways and neighborhood centers.
• The emergence of random transport such as private vehicles, motorcycles.
• Adverse effects of random transport on public health and safety.
• Conducting emissions inspections as part of the vehicle licensing process
• Emission reductions from motorcycles
• Promoting non-motorized modes of transportation such as walking and cycling
• Construction of new roads and bridges
• Improving existing roads inside the cities or linking between new cities.
• The government funded the purchase of new buses and the conversion of existing buses and taxis to natural gas.

Source: Prepared by author based on above references.

All the previous problems facing the existing city and the transformations that are taking place in the extension areas point to the need for a smart transportation system capable of offering high-quality output at a lower cost, while facilitating faster decision-making, through achieving integration between existing transportation infrastructure and ICT (Information and Communications Technologies) and IOT (Internet of Things) This will greatly boost performance, improving urban transportation via improved control systems and sensor technology.

2.3. Formatting author affiliations
The sustainable city is a vision of the future. [20] Define a sustainable city as one that maximizes socioeconomic advantages for its residents while maintaining environmental and equitable standards, as assessed by suitable metrics. Environmentally conscious concepts used to describe cities have spawned projects, and cities like "green city," "eco-city," "low-carbon city," and "smart city" are all used to characterize cities that are pursuing to sustainability. According to [21], 'transportation is critical for economic, social, and environmental growth. Transportation's aim is to carry passengers and commodities effectively while having the fewest adverse effects on the environment and society' [21]. The existing transportation system is a significant contributor to air pollution, greenhouse gas emissions, and degradation of the ecosystem, climate change, and health repercussions. ITS is a critical component in resolving past issues [3]. The most effective way to meet transportation demands is through a smart transportation system. It is not an option to continue to increase the urban population and freight facing megacities and to accomplish and create sustainable cities. Numerous organizations and professionals have defined sustainable transportation, resulting in a variety of definitions. According to [3] that defined sustainable transportation as "any method of transportation that considers humanity, is economical, safe, and offers a variety of modes of travel." Additionally, it is environmentally friendly because it is based on renewable or regenerated energy rather than fossil fuels.

2.4. Concept of Intelligent Transportation System ITS
According to [22] advances in engineering and technology have led many large cities and urban areas to seek to become smart cities as a result of the integration of scientific innovations and their use to provide smart solutions and innovations to sustainable infrastructure, thus enabling them to use their resources efficiently and providing a quality of life for citizens. In smart cities, data is collected from all over the city through infrastructure containing distributed sensors and network structures with communication technology, such as traffic data, weather information, power grids, etc. Communication technology is either wireless or wireless, or both of them. [29] defined ITS in 2001 as "the intelligent and effective application of advanced technologies in areas including data, communication, control,
sensing, and system interoperation on the basis of competitive infrastructure to surface transportation in order to provide real-time, precise, and efficient transport services operating across a wide range." The intelligent transportation system is built of several sensors that perform a variety of sensory functions [22] (Tang, V. W. S., 2006). In general, intelligent transportation systems make use of sensor technology [23]. Loop detectors monitor traffic volume and accidents, automotive type and presence, and speed. To provide a more secure, effective, and timely transportation service for goods and city citizens, the transportation system is currently undergoing a transformation into ITS via V2V, V2H, and V2I communications, in addition to automobile automation and its associated communication structure. Figure 2 shows the concept of a Smart Transportation System [24].

![Smart Transportation System](image)

**Figure 2** Concept of ITS, source: [23]

3. Research Methodology
The paper is structured as follows. Section 1 reviews the current transportation background in Egypt, the novel concept of ITC, the opportunities, and applications, using integrated technologies. And studying its environmental, urban, and economic impacts. Section 2 adopted a descriptive case study conducted on one of the largest cities with a population of more than 20 million and possesses new districts similar to the new cities in Egypt, which is "China's Xiong'an New District". These Chinese cities and their successful experiences with ITS can be used as comparative research cases for scientific and technological achievements to investigate the applicability of ITS. Finally, Section 3 describes a future framework for the development of ITC that has a big potential impact on sustainability in new cities in GC, Egypt.

4. Macro Scale Case study

4.1. China's transport plans and transferring to ITS
China has a high degree of industrial maturity in the application of ITS technology. A complete, open, and powerful domestic industrial chain in China provides a full range of ITS technologies and equipment options. From the perspective of the industrial chain of ITS, the current ITS industry chains in China are fully developed (Fig.3), including communication chips, communication modules, terminal equipment, vehicle manufacturing, software development, data and algorithm provision, and high-precision positioning. The entire industry chain has formed a certain scale of competition and cooperation in all aspects. It is estimated that the market size of China's smart transportation-related market will reach 159 billion yuan in 2023. In June 2014, the official document from the Chinese Ministry of Transport "Guidelines for the Construction of Urban Public Transportation Smart Application Demonstration
Projects" made specific requirements for the smart construction of public transport in terms of system architecture, system functions, information resources, basic conditions, standards and specifications, and operation management, including building a complete set of monitoring system for public transportation operation status, construction of urban public transportation data resource center, construction of smart dispatching platform for urban public transportation enterprises, construction of passenger travel information service platform, construction of urban public transportation industry supervision platform. In 2018, the Ministry of Transport announced that 12 cities, including Beijing, Guangzhou, and Shenzhen, were awarded as "National Public Transport City Construction Demonstration Cities" and more are in the process of such development (figure.3).

4.2. Minor Scale Case Study - Xiong’an New District

At present, there are more than 100 cities under construction of public transportation cities. The construction of public transportation smart systems has become an important development strategy for leading Chinese cities, and the creation of "transit cities" has also become the development goal of major cities. Therefore, the development and construction of smart public transport systems has a good foundation and coverage in major cities in China, and it is also the world's largest urban smart public transport trend. China's ITS construction experience can provide support for the construction of Egypt's smart public transport system. Referring to [30], China’s Xiong’an New District at figure. 4 (near Beijing) is currently building the world's most advanced ITS system to build a new urban smart transportation system with real-time perception, instant response, and smart decision-making. Promote autonomous driving demonstration applications in the Rongdong area, and build an open smart networked area [26] promote the application of shared smart vehicles, develop customized public transportation systems, and realize the smart allocation of urban public transport and shared car resources. This is a good opportunity to use this case as a reference to the new district of Cairo. Therefore, the experience of ITS and smart city applications in Chinese cities is highly adaptable and compatible with the situation in Cairo, and can meet the development needs of the new district of Cairo.

Figure.3 Map of China's Smart Transportation Industry Chain. Source: [25]
Based on city-road-station-vehicle-person "cyclic operation, a structure of ITS - smart city Synergetic system can be designed as Figure 5 and 6.

**Figure 4** Map of Xiong’an New District. Source: [27].

**Figure 5** Structure of ITS and City synergetic system. Source: [28].

Policies, laws and regulations and management innovation consciousness
5. Discussion
As followed procedures resulted and inferred from what has been studied in the previous part and the case study, the mechanisms for implement the framework will be presented in the form of procedures that illustrate each step of the proposal. Then the methodology for dealing with and the presentation of actions, outputs and impacts on the environment, urban and economic levels will be shown in table 2.

5.1. Analysis on planning elements and characteristics of public transport system for new City
Obtain the comprehensive status quo, passenger flow and traffic volume, residents' travel characteristics and needs, transportation and urban planning related professional planning of the typical city's public transportation system and the new urban area to form a basic data set for research. Analyze basic data sets, refine planning and design elements, form a public transportation system and a new urban planning element set, and deconstruct the hierarchy and structure of the element set, and use machine learning and other methods to deeply analyze the interaction mechanism between land use and urban transportation.

5.2. Feasibility evaluation of ITS in new city
Based on the interactive mechanism of land use and urban traffic, the demand database is shared, and a multi-mode network flow distribution model under dynamic information conditions is constructed. Improve and establish the application logic framework, physical deployment framework, and key technical systems (including standard specifications) of the smart public transportation system, and fully describe the blueprint of the future smart public transportation system and its service functions, and provide references for the research and development, engineering construction, and system deployment of the smart public transportation system Basis and knowledge base.

5.3. Development of smart public transport management simulation system of new city
Based on ITS standard design, with dispatching business as the main line, to meet the needs of transition from a three-level dispatch mode to a two-level mode, select typical stations and routes in the New City for smart public transportation system design and development, and build a station-level and network-Level simulation model and carry out simulation test and verification, establish the New City smart public transportation management simulation system.

5.4. ITS system Pilot Model in new city
We provide detailed information for the proposed ITS system and the required technologies for each module in the previous question. The proposed system will be applied on two buses and three bus stop
stations as a starting point. Therefore, the previously mentioned technologies will be required for each bus. The proposed transportation management center is designed to have different servers to be able to analyze and store the received data from all the buses and bus stops. These servers will require licensed software as windows and SQL server and hardware as power units, rack, switches. The data management center will use an IOT platform and build a custom dashboard to present the analyzed data. Also, the data management Centre will need an API for a map such as a google map to track the buses and determine their speed and direction.

**Figure.7** The methodology of the framework. Source: Prepared by author.
Table 2. The proposed Future framework for sustainable transportation in new cities

| The stages | Actions | Outputs | The proposed system Impact |
|------------|---------|---------|---------------------------|
| The design and test of the smart prototype | Building an IOT network in the transportation sector. The design requirement is to provide travelers and authorities with updated traveling information (e.g., the arrival time for upcoming buses, bus density, and availability of seats). Provide authority with traffic monitoring and congestion information based on cameras or sensors and finally automatically saving power. | The complete design of the IOT network will consist of IOT devices, configuration, and location of devices, gateway configuration, and programming (e.g., raspberry pi or microcontroller). | Environmental: Reducing traffic congestion due to a huge number of citizens who will use this comfortable transportation network over their private car. This will lead to reducing air pollution, wasted time and energy consumption. |
| Building the prototype | Providing the final design equipment and devices approved and tested in the previous stage, a few transportation modes should be built as the approved design. | This will provide tested and modified prototype. Moreover, avoid delays and any expect technical issues during the implementation. | Urban: Increase accessibility to modes of transportation by modifying interfaces and reducing cognitive demand. |
| Building a management center application | Utilizing an IOT platform (e.g., Thingworx) to build an application to collect and analyze the data collected from IOT networks in the transportation modes. | Showing this information to the management or authority party in map, graphs, and charts form. Furthermore, it also provides transportation modes with updated schedules and arrival times. Moreover, it alerts management, travelers, and drivers by changes due to emergencies. | Enhance real-time planning by taking into unforeseen occurrences that may benefit or detract from transportation operations. |
| the mobile application | The mobile application for the driver will be developed in the stage of building the management application. | The mobile application provides the driver with real-time information (e.g., route states, congestion, and expected delays). It allows drivers to report the change of route, breakdowns and to call emergency services | Manage the communication and image processing part in the project (data transportation, communication, Wi-Fi). Make interactive transportation modes accessible to the entire population, because it serves as a public access point to a digital transportation system (DTS) that enables access to anyone without the need of applications or a smart phone. |
| Building the traveler mobile application | The mobile application will happen parallel with the driver application development in the previous stage | The traveler app will allow travelers to navigate and plan trips through the city. It will provide real-time updates to bus locations and estimated arrival time to transportation modes, the availability of seats, and transportation modes' density. Furthermore, it alerts travelers of changes of routes or schedules to their upcoming journeys. | Economical: Improves the workability by providing the services that allow them affordable rides to work. It expands their employment options. The companies consider PT options in their selection of locating or relocating facilities. Enable it to function as a public access point and a travel assistant for users who are low-income or disadvantaged. |
| | | | Maintain an appealing and personalized user interface; this may help increase the penetration of trip planning applications and their use by various user groups (elders, immigrants, with special needs etc.). |
| | | | Manage the communication and image processing part in the project (data transportation, communication, Wi-Fi). |
| | | | Social: Suits all the citizens in the new cities and enhances the livability of those citizens by providing them with a comfortable, unpolluted, healthy and safe place to live. |
| | | | Enhance the safety and security of public transit passengers. |
| | | | Streets provide access for emergency vehicles. |

Source: Prepared by author.
6. Conclusion and Recommendation
The study highlights the general transportation problems in the GC, and particularly in the new Egyptian cities. The study proposed a future framework for sustainable transportation and to make it possible by implementing the smart transportation system and developing this sector. Despite that, this study faces several limitations because ITS is a vast field that consists of some groups of applications and technologies. However, these limitations can be considered for future studies and research. The research recommends that authorities and decision-makers adopt sustainable solutions for a sustainable life through emerging technologies such as IOT, big data, cloud computing, and artificial intelligence. We suggest building a synergy model of urban land planning and public transportation operation services that will form the future framework of a smart transportation system that includes a complete travel chain of sustainable "city-road-station-vehicle-person" cyclic operation. Regarding the recent achievements of "public transportation cities" and the operation experience of smart transportation systems in large and medium-sized cities in countries like China, we recommend selecting new areas of similar types in new cities with similar scale and passenger flow characteristics to the new cities of GC for comparative research and using "BIM+GIS and ICT+ IOT" as a representative technology application, the study aims to propose the system design method of smart public transportation including stations, network and management centre under the scale of urban new cities.

After designing and developing the smart public transportation system for the typical stations and routes, we constructed the station-level and network-level simulation models and carried out simulation tests and verifications. Then, considering the development conditions and needs of the Egyptian city and making a technical selection of the smart transportation facilities and equipment, we aim to build a demonstration project to operate the smart public transportation system in the new cities.

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