**Research Paper**

# Towards Smart Cities: Smart mobility challenges and solutions

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**ABSTRACT:** *More than half of the world's population lives in urban areas resulting in critical problem as air pollution, infrastructure problems, high energy consumption and more waste production in large cities. Urban mobility is responsible for 40% of the total CO2 emissions of road transport, which is considered a main factor contributing towards air pollution throughout the world. Mobility is one of the major problems in large cities that involves environmental, social and economic aspects and considered a major issue for cities throughout the world. Mobility needs contribution from both technology and citizens'. Smart mobility is a recent topic that gained an international attention in the last two decades and is spreading very fast controlled by Information and Communication Technology (ICT) in a form of applications for optimizing traffic management and public transportation services. Smart mobility is considered an important aspect of smart cities planning. Smart cities are perceived as a positive approach towards solving some critical urban problems, aiming at reducing the environmental footprint and creating a better lifestyle and quality for citizens. The research will explore "smart mobility" concept including its main principles, advantages and challenges. The research aim is to examine smart mobility impact on economy, society and environment on the short and long-term basis through analyzing smart mobility case studies in several smart cities as Masdar City, Barcelona & Singapore. Based on this comparative study, the paper will propose some recommendations for better implementation of smart mobility principles towards achieving more sustainable smart cities.*
**KEYWORDS:** *Smart mobility, Smart city, Information and Communication Technology; Traffic management.*

## I. INTRODUCTION

Transportation sector contributes to a large extent towards air pollution and greenhouse gases as shown in Figure 1., especially in less developed countries. By using emerging technologies, transportation now can be "smart" and be more efficient for users' needs. "Smart mobility" is all about high-tech infrastructure that saves resources by totally depending on technology for achieving maximum efficiency, accessibility, affordability and safety across various transportation modes. Therefore, Smart Mobility is one of the most promising topics in Smart Cities, as it is capable of ensuring positive benefits for the quality of life of city citizens.
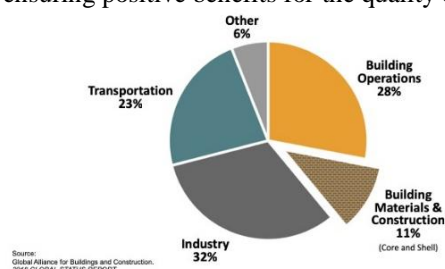


**Figure 1: Transportation sector CO2 emission 2018 [1]**

The term "Smart City" was first introduced in the late 20th century. It evolves around implementations of user-friendly information and communication technologies for achieving more efficiency in urban spaces. Smart cities promote several strategies through applying social and technological innovations by developing high-tech infrastructure for reducing global climate change and depletion of non-renewable energy resources [2]. Smart cities are a result of knowledge and creativity strategies aiming at enhancing the socio-economic, ecological, logistic and competitive performance of cities. Such cities depend on a mixture of human capital as Human capital, Infrastructural capital, Social capital and Entrepreneurial capital [3] as shown in Figure 2.
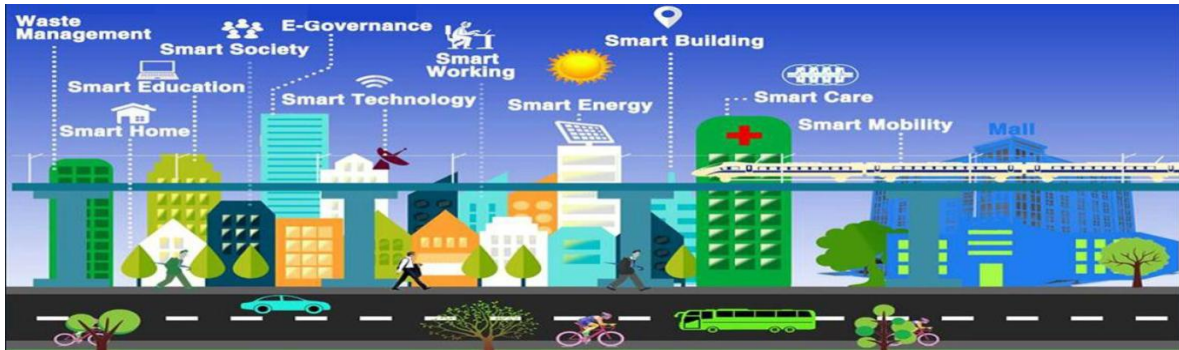
**Figure 2:Smart cities concept [4]**

There is a continuous growth of cities around the world with using today's technology, there will be multiple opportunities for citizens to relocate to new urban areas by depending on new transportation methods. Cities are full of transportation modes and pedestrians, so cities need to shift for smarter transportation, which is more efficient and green. Smart mobility helps to improve efficiency of transportation systems and distribution across routes and time. Smart mobility includes smart parking, smart ticketing, bike and car sharing. Smart mobility is the main pillar for smart cities success [5].

## II. SMART MOBILITY

Smart mobility is the innovative traffic and transport infrastructure which saves resources by depending on technology as shown in Figure 3 for achieving the maximum efficiency. Smart mobility involves several context as accessibility, affordability, compact urban development and safety [6].
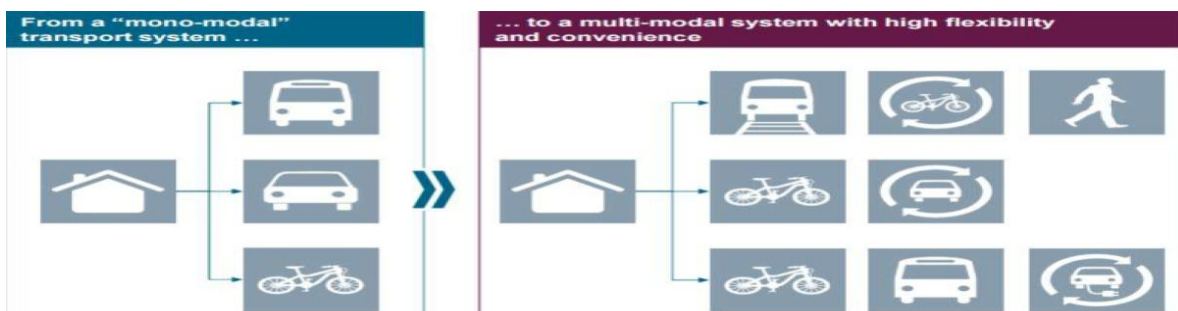


**Figure 3: Smart transportation modes via using Wi-Fi service [5]**

Smart mobility is a crucial topic and has a direct impact on several dimensions of smart city. Smart mobility includes transportation modes and services while enhancing the economic, environmental and human resources by promoting [7].

- Convenient and safe multimodal travel;
- Speed suitability;
- Accessibility;
- Management of the circulation network;
- Efficient use of land.

### 2.1. Smart Mobility Principles

Smart mobility include several main principles as demonstrated in Table (1), to achieve cities citizen's needs & goals such in reducing traffic congestion, accessibility & reducing environmental pollution to achieve high productivity and better life style.

**Table 1. Smart Mobility Principles [7]**

| Principle | Description |
|---|---|
| **Location Efficiency** | Integrate both transportation and land use in order to achieve:<br>■ High levels of non- motorized travel and transit usage;<br>■ Reduced vehicle trip making;<br>■ Shorter average trip length while providing a high level of accessibility. |
| **Reliable Mobility** | ■ Manage, reduce, and avoid traffic jams by supporting optional routes and network management;<br>■ Provide predictability and capacity, increases the focus on traveling which supports economic activity. |

| Health & Safety | ▪ Design, operate, and manage the transportation systems to reduce serious injuries,<br>▪ Promote active living, and lessen exposure to pollution. |
| Social Equity | ▪ Provide mobility for people who are economically, socially, or physically disadvantaged in order to support their full participation in society;<br>▪ Design and manage the transportation system in order to equally distribute its benefits and burdens. |
| Robust Economy | Invest in transportation improvements that support economic condition of the city , local governments and the welfare of residents. |
| Environmental Stewardship | Protect and enhance the city's transportation system, its built and natural environment leads to reduction of transportation system's emission of Greenhouse Gases (GHG) that contribute to global climate change. |

## 2.2. Smart Mobility Advantages

Smart mobility aims to provide cleaner & safer efficient travel modes ranging from different levels such as buses, subway, scooters, bicycles, etc. The smart transportation facilities are not only controlled by governmental authorities but also through private partnerships. Several private organizations sponsor smart mobility to promote towards smart cities'[8].Smart mobility today is already being applied in various cities around the world for its  multiple advantages as illustrated in Table.2.

**Table 2.Smart Mobility Advantages [8]**

| Safety | Smart mobility ensures safety as the road injuries are drastically reduced. |
| Cleanness | Smart mobility focuses on green solutions and reduction of environmental waste as fuels and greenhouse gases. |
| Time management | Smart mobility various transportation modes reduce travel time and ensure time efficiency for smart cities citizens. |
| Integration | Smart mobility implement transport modes integration to ensure efficiency |
| Connectivity | Internet technology (IT) made it easy for users to reach their destinations through virtual maps &a applications with a click of a button. |
| Reliability | Navigation technology today is reliable and efficient. |
| Convenience | Mobile apps are available ,and easily accessible as a result of user-friendly applications. |

## III.    MASDAR  CITY

Masdar city was established since 2006 in Abudhabi,United Arab of Emirates. The city concept was to build a new city extension that has zero carbon emissions and resources efficient by implementing smart strategies. Traditional transportation systems in Masdar city is not allowed for their carbon emissions. Masdar city applied car-free strategy and smart transit systems for more sustainable city. The initial mobility plan of Masdar city was the Personal Rapid Transit (PRT) and the Freight Rapid Transit (FRT) for goods transportation cities'[9]. Smart mobility in Masdar city includes 5 main strategies as personal rapid transit (PRT), Freight Rapid Transit (FRT), Light Rail Transit (LRT), Group Rapid Transit (GRT) and Pedestrian Friendly Streets [10] as illustrated in Figure 4.
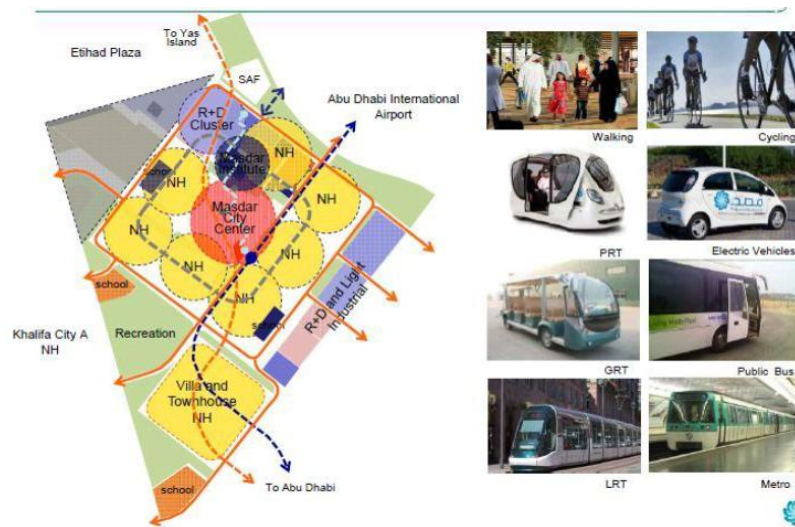


**Figure 4: Masdar City Smart Transportation Modes[10]**

### 3.1. Personal Rapid Transit

The Personal Rapid Transit (PRT) vehicles are air conditioned, comfortable and have no harmful emissions which make them exceeds conventional public transportation systems as shown in Figure 4. The vehicles control panel consists of an information touch screen that controls its destination, doors, activation and emergency stop. (PRT) are driverless vehicles with an advanced navigation system, they use magnets that lie beneath the streets to detect their positions and sensors to detect any obstacles in their path. They are connected through a wireless internet connection to keep them linked with the central computer system of Masdar city to guide them on their destinations and ensure smooth and safe operations to all (PRT) vehicles [9].The (PRT) vehicles are powered by a battery that recharges itself while standing in the (PRT) stations between trips. These stations benches are made of polished low-carbon concrete. There are four berths for four (PRT) vehicles at any one time, while recharging panels in the berths mean vehicles can recharge while standing in the station [10].

### 3.2. Freight Rapid Transit

The Freight Rapid Transit (FRT) vehicles include underground trucks and vans to deliver goods betweenMasdar city and Abu Dhabi. The (FRT) also are designed to transport waste from the city for reusing or recycling [10].

### 3.3. Light Rail Transit

Masdar implemented a wireless-controlled smart electric light rail to carry the passengers at higher capacity and speed [10].

### 3.4. Group Rapid Transit

Group Rapid Transit (GRT) is a new form of collective public transport system depending on smart small automated electric "Cyberbuses" to provide trips and shuttle services. These smart transportation system is easy to use, the passenger just presses a button at the (GRT) stop area to call the (GRT) and then select the destination. This ensures less waiting times and vehicles is operated only when demanded to reduce traffic jams [11].

### 3.5. Pedestrian Friendly Streets

A remarkable aspect of Masdar city is the linear parks that traverse the city. These parks are oriented to direct the prevailing wind into the city. These parks bring cool air into the center of the built environment. They also provide shade and seating areas for residents, workers and visitors. These parks and streets are shaded, encourage outdoor activities and social interactions and other recreational facilities. In addition, plants and trees in Masdar city are selected from indigenous species that can adapt with the harsh climatic conditions and have low water demand for irrigation[ 10].

## IV.    BARCELONA CITY, SPAIN

### 4.1. Smart Parking System

Barcelona city has implemented a wireless sensor system for parking lots in order to facilitate the public parking. The parking system include electromagnetic sensors which are located under each parking lot asphalt and can identify the available parking spaces & show notifications for the citizens through sending the information to a Central Management Unit (CMU)[ 12]. Smart parking systems are mainly found in Barcelona city commercial centers & public buildings parking. The smart parking systems succeeded in reducing traffic cognitions & (GHG) emissions [13].

### 4.2.  Bus Transit system

Barcelona transport system has integrated a new bus network consisting of horizontal, diagonal and vertical lines to ensure safety and efficiency as illustrated in Figure 5. The bus stops use hybrid environmentally friendly buses. The bus stops stations have interactive touch screen that show information & bus routes [13].

**Figure 5:Barcelona city bus stops lines[14].**

### 4.3. City bike systems

Barcelona streets are bicycle friendly. Cycling is considered a main transportation mode in Barcelona city. The Spanish government implemented a city bike systems known as "Bicing". Cycling reduce accidents rates, public transportation and traffic cognition and reduce air pollution and harmful emissions [12]. There are bicycles parking stations near to metro station, main public parks and plazas as shown in Figure 6.



**Figure 6: Bicycles parking in Barcelona central streets[12].**

## V. DISCUSSION

Masdar city smart Masdar city had promising potentials of applying smart mobility systems to supports its main goal of being the first sustainable city in the world with zero carbon emissions. The research has illustrated previously the different smart modes of transportation that Masdar City. However, till today in 2017 ,Masdar city hanged its transportation system to reduce the expensive costs of total 24 billion dollars. Masdar city Personal Rapid Transit (PRT) attempt failed for in- sufficient economic resources [15].

Barcelona smart mobility plan is considered as a successful example of smart cities. Smart cities don't necessarily require high economic resources especially with the international economic crisis that the world recently faced. Instead Masdar city should have depended more on applying Transit Oriented Development (T.O.D) by creating dense, pedestrian friendly streets, more walkable communities that will greatly reduce the need for driving and energy consumption. (T.O.D) beside other environmentally friendly transportation modes could have been more successful for Masdar City and could have helped in achieving its main goal without consuming too much economic resources.

### 5.1. Smart Mobility pros and cons

Different cities around the world already applied smart mobility principles that improved their citizens' lifestyle and improved their cities infrastructure. But on the other hand, there are still some disadvantages of smart mobility as a result of using high technology, which need to be considered. These advantages and disadvantages are illustrated in Table (3).

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**Table 3.Smart Mobility pros and cons**

| Pros | Cons |
|---|---|
| ▪ Improving the infrastructure;<br>▪ Economy development;<br>▪ Environmental benefit (Smart energy management);<br>▪ Economic Sustainability;<br>▪ Reducing energy consumption;<br>▪ Reducing CO2 emissions;<br>▪ Enable better services to its citizens;<br>▪ Reduce non-renewable resources depletion. | ▪ Smart mobility cannot overcome issues such as bad building location and slums areas;<br>▪ Smart mobility relies on constant monitoring and analysis of data for smooth operations. This constant monitoring can have negative impacts on citizen morale as the technology can be considered an intrusion of privacy.<br>▪ Data that can be used to find a parking spot can also be used for surveillance;<br>▪ Creates social risks as elder individuals have a limited knowledge of internet usage. |

## VI.    CONCLUSION

Smart cities are the latest 21st century trend, using technology to improve citizens' life quality in urban spaces. Smart cities both improve environmental quality and promote better services to the citizens. Technology has the power to create more responsive communities to the citizens by responding to their needs and saving their resources. Applying smart technology applications will reduce energy consumption, enable better services to the public, improve efficiency, reduce (GHG) and reduce waste for more sustainable future. "Smart Mobility" as a concept, needs to be broader. This issue is somehow difficult to be applied by governments in less developed countries. Smart mobility doesn't necessarily must depend on high-tech to operate. Not every city in the world is accessible to the internet and invests in technological applications. Instead, smart mobility can integrate with Transit Oriented Development (T.O.D) by designing more walkable comminutes, high density mixed use areas, enhancing multi-modal connections and reducing the amount of parking for personal vehicles to encourage public transportation. (T.O.D) will be more feasible and applicable in less developed countries as it doesn't depend on high-tech.(T.O.D) and smart mobility are complimentary pillars for more sustainable and smarter cities. Several countries as Barcelona, Spain and Copenhagen, Denmark apply new user-friendly applications and facilities to make it easier for ordinary citizens that have medium education and from old age group to switch to smart transportation systems with the minimum effort. These countries have a future vision towards achieving more sustainable future and conviction about citizens' participation plays a big role of the "smart city" concept success. For example, Barcelona has a free WI-FI accessibility in mainly all of its streets to make the internet more available to citizens, as it beliefs that each citizen has the right to use the internet without any charge for his comfort and for the benefit of the country.  But what is the cost and impacts of using high-tech known as "internet of everything". Not all countries around the world have the opportunity, potentials, visions and knowledge for applying such concept. In less developed countries and countries that have political and economic issues, smart mobility and high-tech usage are usually not available and are not easily accessible. In these countries, it will be very difficult to apply smart mobility concept. Instead simpler strategies can be applied that doesn't need technology or internet as encouraging the idea of car sharing "carpooling", mixed used streets, planning more walkable parks and applying bicycle lanes.

## VII.    RECOMMENDATIONS

▪ New technologies must be assessed based on their benefit for the public interest;
▪ Support innovative ideas of cities citizens through active public participation;
▪ Educating and increasing the awareness of the citizens from all backgrounds about the
▪ multiple advantages of using the internet as a tool to improve and facilitate their daily life;
▪ Applying smart sensors in infrastructure could be majorly impactful in two ways. First, the  city will become more sustainable by saving energy. Second, the money that citizens will save in wasteful energy use will increase their income;
▪ Integrate both smart mobility principles and Transit Oriented Development to achieve the maximum efficiency of transportation systems for more sustainable infrastructure.

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