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Towards Sustainable Urban Transportation Case Studies

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***Abstract*—**Climate change is one of the greatest environmental, economic, and social challenges of our time. Urban transportation has had a major negative impact on our environment—most of our air pollution comes from transport.

This paper explores ways to move toward a more sustainable transport system by focusing on creating a more efficient and livable city and improving the environmental efficiency of transport activity. The analytical study covers some international examples of applying sustainable transportation and uses them to suggest a frame work to develop the transportation system in Egypt to be sustainable and more intelligent.

***Keywords*—**Eco-efficiency, electric vehicle, liveable city, sustainable transportation.

I. Introduction

TRANSPORTATION is an essential part of urban design and in the functioning of livable cities. There are a number of beneficial forms of green transportation that support and enhance walkable urbanism. These green transportation options make our lives easier, reduce congestion, reduce our dependence on cars and oil, are safer and less costly, help save the planet, and make life more efficient. This paper assesses Cairo's transportation problems Egypt currently faces and gives an overview of the sustainable transportation strategies, by focusing on international case studies that have applied sustainable transportation systems on their urban environment. This paper highlights the frame work that integrates technology and intelligence into the transportation infrastructure and provides orientation for transport planners and policy makers who wish to promote sustainable urban mobility in their cities. Following that, it offers recommendations for the Egyptian context to make its transportation systems more sustainable, efficient, and safe.

II. Research Problem

The city in the 21st century faces major challenges, including rapid urbanism, wasteful consumption of resources, transportation congestion, and environmental degradation.

The problem of constant traffic congestion is quite serious; cities around the world are being wrecked by the ever-increasing burden of traffic. A significant part of the problem is the enduring popularity of the private car—still an attractive and convenient option to many, who turn a blind eye to the environmental and public health impact. Public transport always seems to take second place to the car.

Trends such as a continuous outward expansion of development, unsustainable ways to deal with transportation and the ever-increasing need for more transportation capacity threaten both the sustainability and the livability of our urban environment.

So this paper answers the following questions:

- What is the meaning of sustainable transportation and what are its major applications?
- What are the principles of sustainable transportation?
- How have cities applied the concept of sustainable transportation on their urban environment?

III. Research Objectives

This paper develops guidelines for sustainable transportation, specifically in Cairo. This is achieved through a combination of sub-objectives as follows:

- Use smart alternative ways of transportation to achieve sustainability of the built environment.
- Create communities that are livable, walkable, and sustainable, while raising the quality of life.
- Make smart transportation by the improvement of urban transportation.
- Develop the visual image of cities by highlighting the importance of sustainable transportation, to consider the operations of urban design, and to provide an attractive and safe urban environment for all users.
- Provide a solution for a sustainability framework that will allow people to quickly and easily move about our cities without continuing to pump the amount of dangerous CO2.
- Make transportation options such as walking, biking, and transit safer and more convenient, and neighborhoods more livable, walkable, and connected.
- Transform from a life based on fossil fuels to a future based on renewable energy.

IV. Research Hypoehesis

This paper assumes that by applying green intelligent transportation systems cities can achieve sustainable urban design processes and create livable cities.

V. Research Methodology

The paper explores the concept of sustainable urban transportation from theoretical, analytical, and practical viewpoints aiming for sustainability. It seeks to identify the basic features of sustainable urban transportation. Next, it analyzes how the concepts of international case studies were

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developed and explores a practical approach toward sustainable transportation systems. Finally, it suggests a set of recommendations to develop the urban transportation system.

VI. Sustainable urbanism:

"New urbanism promotes the creation and restoration of diverse, walkable, vibrant, mixed-use communities composed of the same components as conventional developments but assembled in a more integrated fashion, in the form of complete communities. Such communities contain housing, work places, shops, entertainment, schools, parks, and civic facilities essential to the daily lives of the residents, all within easy walking distance of each other. New urbanism promotes the increased use of trains and light rail, instead of more highways and roads, minimal environmental impact of development and its operations, eco-friendly technologies, respect for ecology and value of natural systems, energy efficiency, less use of finite fuels, more local production, and more walking, less driving" [1].

"Beyond urbanization, the 'livability' of our communities is an important issue that many government organizations around the world are attempting to address. Community livability applies a refreshing approach to environmental and social concerns such as traffic safety, public health, opportunities for recreation, and entertainment among others. Livability embraces the idea that hyper-motorization erodes the social and economic vitality of a city. Improved walking and cycling conditions, transportation affordability, increased security, health and safety and reduced emissions will all contribute to an overall improved livability in our communities" [2] .

VII. Liveable City

"Many aspects of urban design and new approaches to city form are based on the concept of livability. Livability is critical to the establishment of a sustainable community. It forms part of the sustainability equation" [3]. "Liveable cities offer a high quality of life, and support the health and wellbeing of the people who live and work in them. Liveable cities are socially inclusive, affordable, accessible and safe. They also feature attractive built, and natural environments" [4]. "The idea of livable cities is dual—the basics need to be in place (i.e., clean air and water, energy, and waste management" [5]. So, liveable cities promote the benefits of sustainable urban transportation to move towards health, safe and attractive urban environment.

VIII. The Need to Change Our Current Transportation Towards Sustainability

Sustainable and liveable cities need efficient and affordable solutions for local public transportation due to a range of major factors, such as:

1. "A rapid population expansion: One of the most well-recognized root causes of transportation system congestion is the relentless growth of world population.
2. Hyper-Urbanization: An increase in a population in cities and towns versus rural areas.
3. Globalization: The impact of globalization on transportation has been to increase the traffic across all types of transport between urban centers, and charged demands for increased speed, security, and reliability.
4. Pervasive information and communications technology" [6].

IX. The Sustainable Transportation

"Transportation plays a key role in the global economy and in the challenges and opportunities associated with sustainable development. Sustainable transportation can define as The use of renewable resources, minimizes consumption of non-renewable resources, reuses and recycles its components, reduce carbon emissions on all transport modes and minimizes the use of land and the production of noise" [7]. "A sustainable transport system must meet the mobility and accessibility needs of the people by providing safe and environmentally friendly modes of transportation. This is a complex and difficult task in the mega-cities of developing countries" [8].

"Transportation systems are also considered smart when they are applied to achieve smart policy goals in the urban environment, such as lower emissions, reduced fuel consumption, improved safety, or economic competitiveness" [9]. "Smart/sustainable transportation is green and it is a planning and administering intelligent transportation networks. There are a number of beneficial forms of green transportation that support and enhance walkable urbanism. These green transportation options make our lives easier, reduce congestion, reduce our dependence on cars and foreign oil, are safer and less costly, and help save the planet" [1].

X. Sustainable Transportation System Applications

"Transit friendly design should support a high level of transit activity by encouraging alternative transportation" [10].

A. Transportation Alternatives

"The greenest and most sustainable forms of transportation are trains, bicycles, and walking. Some of the world's best and fastest trains have been in operation for more than 25 years in Europe, and more than 40 years in Japan. These include futuristic high-speed trains and others such as the following" [11] ;

Trains:

Modern high-speed trains such as the Eurostar, the French TGV, Japanese bullet trains, regional trains, monorails light rail; trams; trolleys People movers. Clean electric trains are a major form of daily transportation in numerous countries, and are the single most powerful transportation choice that can solve serious mobility, energy, environmental, economic, health, and social problems on a global scale.

High-speed rail delivers faster, more efficient mobility for less money and energy than roads and airports combined.

Bicycles:

Bicycles are the most sustainable form of transport, are the least expensive to use, are pollution-free, take up the smallest amount of space for riding and parking, and provide daily exercise for riders. Bicycling creates safer streets, reduces the causes of global climate change, promotes a healthy

environment, and limits the effects and health care costs related to inactivity.

Scooters:

Scooters electric and push types are heavily used in urban areas as daily transportation, they can reduce air pollution also.

Walking:

Walkable communities allow residents to walk to services, shopping, schools, and jobs and can reduce traffic congestion, air pollution, and improve public health.

B. New Vehicle Technology

"Governments regularly subsidize research into technologies to improve automobile fuel efficiency. Efforts to improve the fuel-efficiency of trucks help reduce the cost of transportation, contribute to greater use of transport" [12]. There are many types of environmentally friendly public transportation, such as;

Hybrid Vehicle:

It harnesses a significant amount of the braking energy and use 30% less fuel.

Electric Vehicle:

It can be powered largely by electricity generated from renewable sources of energy.

Hydrogen vehicle:

A vehicle that uses hydrogen as its onboard fuel for motive power.

MonoMetro:

It is cost-effective, energy-efficient, safe and reliable. Fig. 1

Solar Cars:

They are powered by solar panels an can reduce air and noise pollution.

The fully automatic and driverless Avenio: low-floor tram is another example for environmentally friendly transportation with significant savings potential. Fig. 2

C. Sustainable Transportation Infrastructure

Many cities design for a livable sustainable future by applying sustainable transportation infrastructure, it represents many forms, such as "greenways and foreshoreways, bikeways, busways and railways" [14]. Fig. 3

Fig. 1 MonoMetro as a sustainable transportation system application [13]

Fig. 2 Sustainable transportation for Qatar [13]

Fig. 3 Green Railway – France [13]

XI. The Challenges of Sustainable Transportation

Future transportation must be "smart". Smart transportation should address four main challenges, as follow:

A. Eco-Efficiency

"The smarter system must respect the environment, limiting or inhibiting adverse impacts on it, while also using natural resources efficiently.

B. Mitigating Congestion and Planning Capacit

The smarter system must be able to meet a growing and dynamic demand for transportation and provide for efficiency and consistency.

C. Ensuring Safety and Security

The smarter system must be safe for all users and must minimize exposures to risks.

D. Empowering Transportation System Users

The smarter system must be able to deliver choices to its users, with an array of options that cater to different user segments, reflecting the needs of the segments" [6].

XII. Why Sustainable Transportation?

Urban transportation has a major negative impact on our environment.

- "Worldwide: There are more than 2,500 fatalities and 50,000 injuries each day from traffic accidents. According to the World Health Organization, over 1 million people die each year in motor vehicle accidents.
- The road system is unable to efficiently move the overwhelming number of cars that clog cities daily,

resulting in constant congestion for thousands of miles across the country.
- Money is spent continuously expanding the road system in an attempt to keep up with rising congestion. Governments spend money every day constructing, fixing, and improving roads" [15].
- "Cars are highly polluting; cars produce noise pollution and numerous air pollutants, and they cause a tremendous amount of permanent environmental damage in the form of toxic air, acid rain, crop damage, climate change, and other global warming events.
- Cars are totally dependent on oil, which is a finite resource" (new urbanism, sustainability).
- "Congestion, which creates negative economic, health, environmental, and social impacts, and affects mobility not just at the local (city) level, but also long-distance transport routes that go through urban areas" [15].

From the above, cities should be moved towards a more sustainable transportation system.

XIII. Objectives of Sustainable Transportation

"It is widely accepted that a main goal of a sustainable urban transportation is to limit emissions and waste within the planet's ability to absorb them" [2], "reduced environmental impact" [15], "reduced traffic congestion" [16], improved air quality, reduced greenhouse gas emissions, and promoting public health. The many objectives of sustainable transportation, as follow:

- "partnership for sustainable communities
- provide more transportation choices" [17].
- "energy conservation and emission reductions
- reduced parking problems and reduced traffic accidents,
- reduced costs to build, maintain and operate roadways.
- improved mobility options, particularly for non-drivers,
- reduced land consumption, reducing stormwater costs, heat island effects, and habitat loss,
- supports strategic planning objectives, such as urban redevelopment and reduced sprawl,
- ncreased physical activity and associated health benefits" [16].
- "Higher quality of life and better places to live, work, and play
- greater mobility
- increased transit ridership
- reduced household spending on transportation, resulting in more affordable housing
- greatly reduced dependence on foreign oil.
- greatly reduced pollution and environmental destruction" (Transit Oriented Development).

From the above, "sustainable transportation allows generally accepted objectives for health and environmental quality to be met" [18].

XIV. Principles of Sustainable Transportation

Many requirements and design considerations must be taken into account in sustainable urban transportation. There are four main principles.

A. Making Transportation Sustainable

"Making transportation more sustainable includes designing highways that work best for communities, integrating transit, bicycling, and walking into projects and employing techniques that reduce storm water pollutants" [19] and meeting the social and economic needs of the present without compromising future generations' ability to meet their own needs.

B. Technology

"New technology and innovative methods provide a more reliable, responsible, and sustainable transportation system. They can conserve fuel and energy, reduce carbon emissions, and protect our natural environment while keeping people and goods moving.

C. Efficiency

Efficiency can be achieved by making highways more adaptive with the ability to smooth traffic flow through the busiest choke points. We're using fewer building materials by recycling and extending the lifespan of roads, bridges, and other structures.

D. Reducing the Carbon Footprint

Sustainable transportation helps citizens and businesses reduce their carbon footprints in innovative ways, from expanding transit services and ridesharing opportunities to partnering to build support infrastructure for electric and other alternative-fuel vehicles" [19].

"Smart transportation should help in the development of smart growth communities, create walkable neighborhoods, and provide a variety of transportation choices" [10].

XV. Case Studies of Sustainable Transportation

This section will analyze a set of international case studies in applying the basic principles of sustainable transportation to develop a system in Egypt.

A. Sustainable Transportation of Tokyo

"Tokyo's subway system is among the busiest in the world, with millions of commuters passing through each station every day. Recently, the Japanese government decided to harness the power of all that foot traffic in two of the city's biggest and busiest stations, they've installed 25 square meters of piezoelectric energy-generating flooring tiles in front of the ticket turnstiles. The tiles, made of layers of rubber sheeting and ceramic, absorb the vibrations from the footfalls and capture the resulting energy. The combined energy, which yields about 1,400kW/sec per day, is then stored in capacitors and channeled to the station's ticket gates and electric lights and displays" [20] (Fig. 4).

Fig. 4 Energy- generating subway floor, Tokyo [21]

B. Roadway Design Innovation, USA

"Other designers have integrated solar power with sustainable transportation in even more innovative ways. The Sustainable Highway concept project tries to solve the same issues of decreasing greenhouse gases and improving air quality by changing the roads rather than the cars that drive on them. The Sustainable Highway concept is a lightweight, laminated glass canopy above the roadway that filters dust particles from the roadway before releasing air into the atmosphere. The canopy is also equipped with solar panels that produce clean energy and decrease carbon monoxide emissions" [21] (Fig. 5).

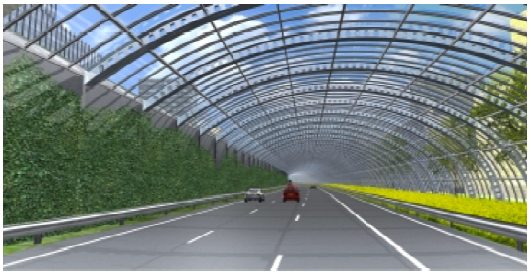

Fig. 5 Roadway design innovation [21]

C. Solar Roadways, Canada

"There are also solar-powered transportation projects that reenvision the road as a giant energy grid rather than a transportation artery. Solar Roadways designed parking lots made out of solar panels. Roads, which go to most houses, stores, and public buildings, provide an excellent grid for moving solar power. Unfortunately, the conventional asphalt road also generates a heat island that exacerbates global warming. Some companies reimagined the road as a solar grid that collect heat and dispersed it to homes as energy instead of into the atmosphere. The solar panels which are developed to do this are insulated between glass sheets and are thick enough for cars to drive on "[20] (Fig. 6).

Fig. 6 Solar Roadways [21]

D. San Francisco Sustainable Transport Strategy

The guiding principles of the city;

1. To ensure quality of life and economic health in San Francisco, the primary objective of the transportation system must be the safe and efficient movement of people and goods.
2. Public transit is an economically and environmentally sound alternative to transportation by car.
3. Decisions regarding the use of limited public street and sidewalk space shall encourage the use of public rights of way by pedestrians, bicyclists, and public transit, and shall reduce traffic.
4. Transit priority improvements, such as designated transit lanes and streets and improved signalization, shall be made to expedite the movement of public transit vehicles and to improve pedestrian safety" [21].
5. "Pedestrian areas shall be enhanced wherever possible to improve the safety and comfort.
6. Bicycling shall be promoted by encouraging safe streets for riding, bicycle lanes, and secure bicycle parking.
7. Parking policies for areas well-served by public transit shall be designed to encourage travel by public transit and alternative transportation.
8. The city and county shall encourage innovative solutions to meet public transportation needs wherever possible" [22]. See, Fig. 7 and Table I.

Three GHG Reduction Strategies:

1. Transit Improvements
2. Complete Street
3. Electric Vehicles

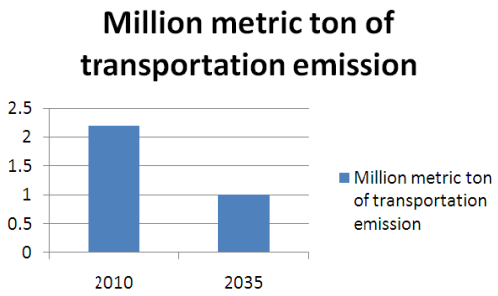

Fig. 7 Transportation greenhouse gas emission pollution [22]

TABLE I
SAN FRANCISCO SUSTAINABLE TRANSPORT STRATEGY [22]

	Infrastructure support		
	Strategy 1	**Strategy 2**	**Strategy 3**
Photos			
	Transit Improvements	**Complete Streets**	**Electric Vehicles**
transportation GHG Reduction Measure	Implement the transit effectiveness project	Expand transit fleet, storage and maintenance to accommodate growth	Allow pilot programs for permeable paving and green streets; revise Level of Service Analysis.
	Expand transit fleet and maintenance to accommodate growth	Prioritize investments in bicycle infrastructure, i.e., cycletracks, class II lanes, and bikesharing pods	Require higher ratios of carshare and bicycle parking, and charging infrastructure in new development
	Dedicate exclusive right of way for the bus and rail network	Identify locations for pedestrian amenities and plazas	Promote incentives for expanding car-share with low-carbon/electric vehicles and electric bicycles
Added benefit of measure	Increase efficiency, reduce travel time, and optimize capacity	Enhance transit services, promote green economy, and decrease travel time	Improves public health and safety, promotes green economy
	Enhance transit services, promotes green economy	Improves public health and safety, promotes green economy	Decreases auto ownership, direct reduction in congestion
	Increase efficiency, promote green economy	Improves public health and safety, promotes green economy	Decreases auto ownership, direct reduction in GHG and VMT, promotes green economy.

XVI. FRAMEWORK - TOWARDS SUSTAINABLE TRANSPORTATION SYSTEM

This section suggests a framework to develop a transportation system in Egypt that is more sustainable and more intelligent (Fig. 8).

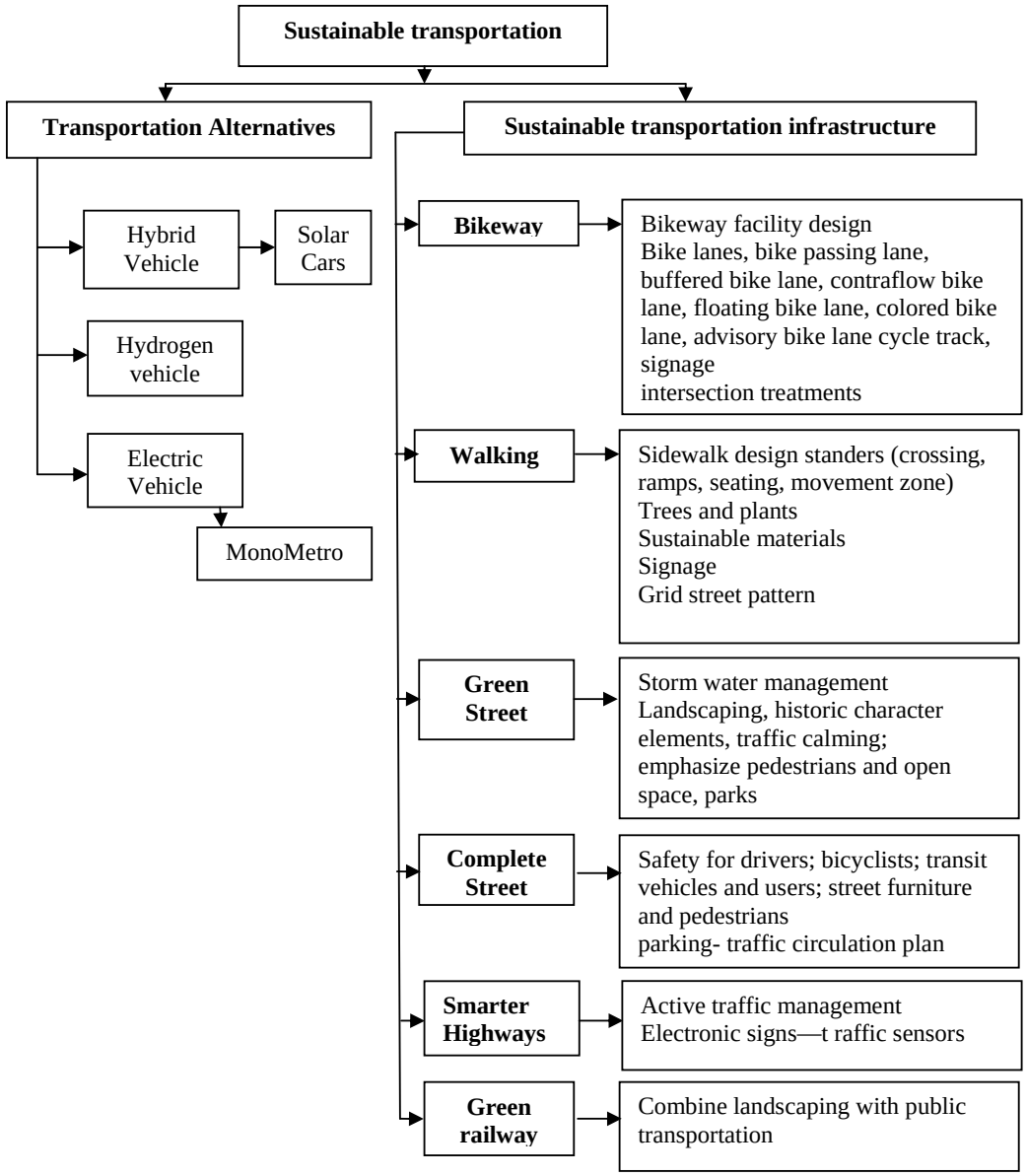

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Fig. 8 Sustainable transportation system – Framework (Source: The researcher)

XVII. Case study of Cairo, Egypt

This section will deal with the city of Cairo to document the most important problems that face urban transportation. Following that the section will suggest a set of future recommendations based on the sustainability framework which is have according to the results of the study to develop the transportation system in Cairo to be sustainable and more intelligent.

A. Urban Transportation Condition in Cairo

Cairo is a historical city; it is an ancient city and center for culture and civilization. The city is dealing with a lot of urban and environmental problems, a high density of population due to rapid growth of urbanization, environmental pollution due to old vehicles, traffic congestion, and unsustainable urban transportation, which negatively affects the visual image of the city, among other things, see Fig. 9, 10 and 11. Designers are faced with urbanization problems and a mobility problem that need to be reversed.

Fig. 9 Traffic congestion in Cairo [23]

Fig. 10 Old vehicles in Cairo [23]

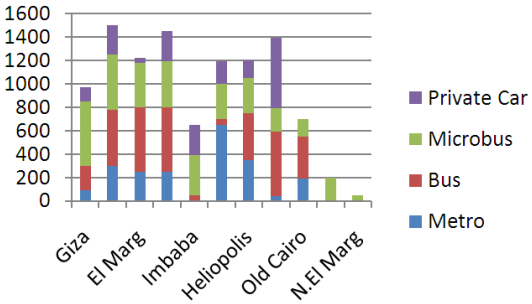

Fig.11 The study for the number of users of transportation systems in different cities in Egypt [24]

B. The Objective

The objective is to develop recommendations to create an efficient, environmental friendly and affordable urban transportation system in Cairo.

C. Future Recommendations for Sustainable Urban Transportation in Cairo, Egypt

Future recommendations for sustainable urban transportation in Cairo depends on the framework that is chosen from the theoretical and the analytical studies. These recommendations can be divided into five main sections, as follow:

Sustainable transportation infrastructure:

Road network infrastructure and cars (complete street):

- Improvements to specific intersections and squares with high traffic bottlenecks.
- Restructuring transportation infrastructure.
- Effective use of public resources: making efficient use of existing infrastructure (public transport, existing road space, etc.)
- Re-imagining the road as a solar grid by designing parking lots made out of solar panels.

Public transportation infrastructure (green street):

- Efficient public transport system: road-based high capacity mass transit systems
- Restructured bus network (formalize the informal).
- Storm water management, landscaping, open space and historic character elements.

Non-motorized transportation (bikeway-walking):

- The city's transportation plan should include bicyclists
- Sidewalk design standers (crossing, ramps, seating, movement zone)
- All street furniture should be made of sustainable materials.
- Piezoelectric energy-generating flooring tiles in pavements.

Improved traffic management practices (smarter highways):

- Solar roadways: The vibrations of cars over the road surface will create energy for streetlights
- Traffic management plans
- Parking strategies/policies
- Enforcement of traffic rules
- Traffic signal upgrading especially in central business districts of Cairo and Giza
- Dynamic traffic management the ability to control the path (route traffic) is critical to alleviating the traffic challenges

Transportation alternatives:

- Developing transportation alternatives by using the environmentally friendly public transportation, such as solar cars, hydrogen vehicle, electric vehicle).
- Decreasing the ratio of pollution by using renewable and clean sources of energy as natural gas
- Reducing costs of maintenance
- Extending the use of clean means of transportation, such as the underground metro, considered the cleanest, and fasted mean of transportation

XVIII. Conclusion

Urban transportation is one of the biggest contributors to climate destruction—and mobility continues to increase in our society. Sustainable cities need efficient and affordable solutions for local public transportation to prevent traffic jams, improve urban environmental degradation and reduce CO_2 emissions

It is important to apply sustainable transportation in a holistic and integrated manner to ensure that key concerns such as depletion of resources, global climate change, disruption of ecosystems, and toxic pollution are effectively addressed.

From the previous study, sustainable transportation can be supported by promoting the use of:

- sustainable transportation infrastructure.
- more energy efficient forms of transportation.

The paper developed the framework to move toward sustainable urban transportation in Cairo, Egypt. As such, the paper suggested future recommendations for the Egyptian context to make its transportation systems more sustainable, efficient, and safe.

XIX. Future Studies

1. Urban bikeway for sustainable transportation.
2. Decision-making on urban transportation.
3. Financing policies and sustainable urban transportation.

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