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SADRŽAJ / CONTENTS

OBNOVLJIVI IZVORI ELEKTRIČNE ENERGIJE U FUNKCIJI ODRŽIVE URBANE MOBILNOSTI

RENEWABLE ELECTRIC ENERGY SOURCES IN THE FUNCTION OF SUSTAINABLE URBAN MOBILITY

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Održiva urbana mobilnost je važan deo urbanog planiranja, koji u sebi integriše ekonomske, ekološke, energetske i društvene uticaje. U većini gradova u Srbiji, ali i u svetu urbana mobilnost se zasniva se na konceptu prekomernog korišćenja individualnih vozila, koja troše goriva bazirana na fosilnim izvorima energije. To dovodi do zagušenja u saobraćaju sa visokim nivoom zagađenja i buke u gradovima, pojave toplotnih ostrva, gubitka vremena i mnogih drugih negativnih pojava u različitim sferama ljudskog delovanja. Rad analizira ove pojave i predlaže neka od mogućih rešenja koja se pre svega odnose na primenu obnovljivih izvora električne energije (OIEE) u oblasti urbane mobilnosti. Korišćenje električne energije za pogon vozila, ukoliko ona ne potiče iz obnovljivih izvora ili reciklažom otpada nije rešenje koje se uklapa u koncept održivog razvoja. U radu se dalje analizira koncept transportnih sistema koji podstiče razvoj i drugih oblika saobraćaja zasnovanih na korišćenju novih tehnologija, kao i sprovođenje koncepta pametnih gradova.

Ključne reči: *obnovljivi izvori električne energije; urbana mobilnost; održivost; pametna mobilnost*

Sustainable urban mobility is a significant part of urban planning, which integrates economic, environmental, energy, and social impacts. In most cities in the world and Serbia, urban mobility is based on the excessive use of individual vehicles, which consume fuel based on fossil energy sources. That leads to traffic congestion with high degree of pollution and noise in cities, the appearance of heat islands, loss of time, and many other negative phenomena in various spheres of human activity. The paper analyzes these phenomena and proposes possible solutions primarily related to renewable sources of electrical energy (REES) application in urban mobility. Using electricity to drive vehicles, if it does not come from renewable sources or recycling waste, is not a solution that fits into sustainable development. The paper further analyzes the concept of transport systems that encourages the development of other forms of traffic based on the use of new technologies and the implementation of the Smart Cities concept.

Key words: *renewable electric energy sources; urban mobility; sustainability; smart mobility*

1 Introduction

Contemporary urban development strategies are focused on sustainable cities with a higher ecological standard, rationality in the efficiency of using land, water, energy, and material resources, and minimal negative environmental impact. Experts believe that cities in the future should become modern spaces for people gathering, available for all social groups, historical founders of culture and knowledge, touristic attractions, and spots of pre-served both natural resources and built heritage. Sustainable cities are considered urban with high economic prosperity, an extensive spectrum of education and job opportunities, citizens' involvement in decision-making government processes, available healthcare services, and the core of scientific achievements.

The mentioned principles for urban development have an inextricable connection with urban transport. The expansion of cities, as well as their development into strong educational and cultural centers, led to an increase in the number of residents, as well as students, and tourists, which was reflected in the increased flow and number of motor vehicles in traffic, and the need to create new pedestrian routes in cities. Traffic problems are becoming more acute in urban areas, and their solutions are more necessary. High dependence on individual traffic, inadequately resolved public transport, the growing need for parking lots, pollution, heat island effects, noise, loss of time, and loss of productivity are just some of the global issues and challenges of cities of all sizes, not only metropolis. Sustainable urban mobility, thus, becomes one of the most important issues in urban centers.

Contemporary concepts of sustainable urban development determine sustainable urban mobility differently. The Livable City concept promotes mobility systems designed to be adaptable to all social groups, attractive and comfortable to use, and most importantly transport which strives for health, safety, and well-being and facilitates future regeneration processes [1]. Urban mobility is recognized as one of the six main dimensions of a contemporary smart city, which implies the integration of information and communication technologies (ICT) into public urban transport systems, non-motorized vehicles, and good accessibility [2]. In recent years, more attention has been paid to participatory urban planning, including the design of the transport system in a way that is more efficient and pleas-ant for citizens, their preferences and previous experience [3]. Further, urban mobility can have a strong influence not only on the environment but also on urban connectivity, and urban design proposals and must be integrated into contemporary civil engineering, urbanists, and architects' practices. The global challenges caused by the COVID-19 virus pandemic have influenced changes in the conventional habits of people's transportation, so the concept of resilient cities indicates the necessity of improving the transportation system to prevent people from completely turning to individual motor vehicles [4].

The subject of the research paper is sustainable urban mobility in contemporary cities. The paper is organized through three basic units. The first part analyzes the negative aspects of mobility in urban areas - population growth, increased means of transport, climate change, negative environmental impact, and the appearance of heat islands. The second part of the paper deals with the concept of sustainable urban mobility and the possibility of applying renewable sources of electrical energy to improve it. The third part of the paper is dedicated to the Smart City concept and the development of sustainable urban mobility within its framework. The paper aims to draw attention to the importance of the development of urban transport systems that will sustainably improve the image of cities, their functioning, motivate citizens to use healthier mobility solutions (pedestrian, bicycling), and urban planners to create innovative, sustainable, and attractive urban areas.

2 Negative aspects of urban traffic

2.1 Population and traffic growth

The number of inhabitants in cities is increasing. Based on the data published in 2016 by UN-Habitat, 54% of the global population lives in urban settlements [5,6]. The urban population is expected to continue to grow so that by 2050, the world will be one-third rural (34%) and two-thirds urban (66%) [7,8]. This leads to a burden on the urban transport system and the public transport system, as well as the necessity to find new, sustainable transport management systems in urban areas.

The increase in the number of inhabitants in cities subsequently caused the increase of overall traffic worldwide. The number of cars in cities will continue to grow, especially in rapidly developing economies. In China, the number of passenger vehicles increased from 5.9 million in 2000 to 91.7 million in 2014. In India, there was an increase from 2.9 million cars to 21 million. The number of cars worldwide is expected to reach 2 billion by 2040, double the 2010 image. Most new car owners will live in urban areas [9]. Multiple authors discussed the distribution of cars, as result of population growth emphasizing the intensive increase in number of motor vehicles [10,11]. All these data indicate that trend of traffic growth is unsustainable and that the concept of traffic in cities needs to be reshaped.

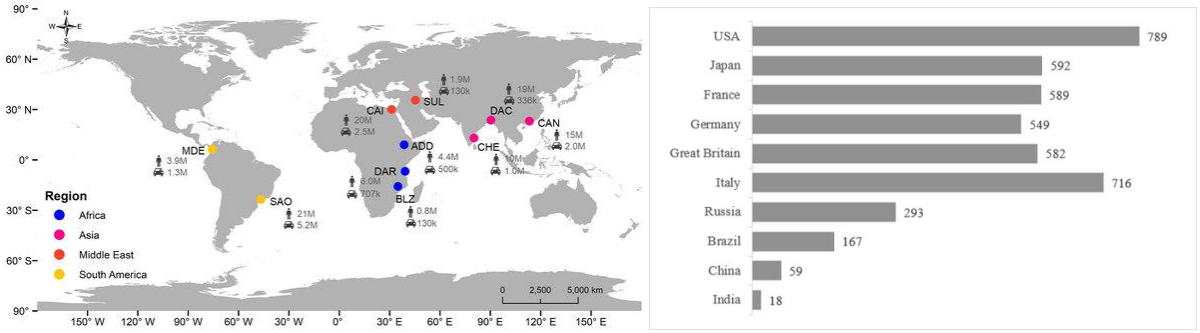

Figure 1: left - Distribution of population and cars in the world cities [10]; right - Number of cars per 1000 people in different countries [11]

2.2 Energy and transportation in cities

With more than 50% of the world's population, cities account for 60% to 80% of energy consumption and generate as much as 70% of human-induced greenhouse gas (GHG) emissions, primarily through the consumption of fossil fuels for energy supply and transportation [12]. The largest number of vehicles, especially in less developed countries, still consume fossil fuels, often of poor quality. Interdependence of transport and other urban systems means that transport disruption can have immense consequences on the functioning of a city. The effects are visible, and they refer to excessive GHG emissions into the atmosphere, the appearance of heat islands which increases the temperatures in cities, increase pollution, and ruin biodiversity and people's health. In the document of Earth Institute, Columbia University [13], among other things regarding energy consumption and transport, the following is written "*urban transport systems are the major emitters of GHGs and are essential to developing resilience to climate impacts; cities account for over 70% of GHG emissions with a significant proportion due to urban transport choices*". The transport sector accounts for nearly 30% of total end-use energy-related CO_2 emissions. Of these, direct emissions from urban transport account for 40%; urban transport emissions are growing at two to three percent annually. The majority of emissions from urban transport are from higher-income countries. In contrast, 90% of the growth in emissions is from transport systems in lower-income countries.

Urban transport accounts for 20–50% of energy consumption in cities (excluding industry) and based on current trends this consumption will experience the highest growth [14]. 20% of average European and US household gross income is spent on car ownership. 90% of urban residents in Europe are exposed to harmful levels of air pollution [14]. Freight accounts for 20% of urban traffic, and it leads to 50% of urban road transport CO_2 emissions and 60% of urban road transport air pollution [16,17].

2.3 Climate changes and urban heat islands

The impact of climate change on cities is undeniable. Cities greatly influence climate change on the planet. Urban and architectural solutions, population density, as well as traffic solutions, types of energy sources, etc. have a great impact on climate change on a local and global level. Excessive use of vehicles, which primarily use fossil fuels, whether in the public or private sector, as well as transport, increases temperature, a higher concentration of CO_2 in the atmosphere, and the creation of heat islands, which significantly affects climate change.

Cities consume a large amount of energy for transportation, which is mostly from fossil fuels. This leads to emissions of gases with the GHG effect, which pollutes the atmosphere and affects human health. Current trends of global urbanization and energy consumption show an increasing consumption of fossil fuels, especially in parts of the world that are rapidly becoming urbanized. The main issues are the following:

1) how to secure a growing need for energy in buildings, transportation, and other systems;
2) how to provide energy security and equal access to energy;
3) how to reduce the consumption of fossil fuels including the reduction of GHG emissions;
4) how to build resilient urban energy systems that can endure and recover after the effects of extreme climate events.

Data in the document provided by Earth Institute, Columbia University [13] show that temperatures are already rising in cities around the world due to both climate change and the urban heat island effect: mean annual temperatures in 39 ARC3.2 cities have increased at a rate of 0.12 to 0.45°C per decade over the 1961 to 2010 time period [1], mean annual temperatures in the 100 ARC3.2 cities around the world are projected to increase by 0.7 to 1.5°C by the 2020s, 1.3 to 3.0°C by the 2050s, and 1.7 to 4.9°C by the 2080s [2].

To reduce the negative impact of transportation on the environment, it is necessary to accept new management techniques and technologies and adopt different strategies that promote greater energy efficiency and the use of renewable energy sources [18]. Sustainable city transport and urban mobility represent only one of the possible solutions for overcoming such obstacles in the cities.

2.4 Environmental issues

Environmental issues are becoming a global priority. Cities are complex systems and big consumers of energy. The consumption of large amounts of energy, water, materials, and all-natural and man-made resources has had a powerful effect on the environment. According to the Intergovernmental Panel on Climate Change (IPCC) Report, cities consume between 2/3 and 3/4 of total global energy and generate 75% of global carbon emissions [19,20].

Transportation is a major polluter. It produces around 20% of the world's CO_2 emissions. Aviation contributes only 8% of all CO_2 emissions from the transportation sector. The main contributors to CO_2 emissions in the transportation sector are: cars, 41%; medium and heavy trucks, 22%; buses and minibuses with only 7% [21]. CO_2 emissions from urban mobility will increase by 26% by 2050. Demand for urban passenger transport could grow from 60% to 70% by 2050 [9].

Population growth, economic development, and continued urbanization will lead to a strongly increasing demand for urban transport. This growth will do more than cancel out any CO_2 emissions reductions made possible by new low- and zero-carbon technologies. Projections see total motorized mobility in cities almost double (+94%) between 2015 and 2050. This growth will cause a 26% increase in CO_2 emissions from urban mobility by 2050 [9].

3 Sustainable urban mobility and the possibilities of applying RES in traffic

3.1 *Sustainable urban mobility concept*

Solving the problem of energy overconsumption in cities, whether it is a question of energy inefficient buildings, transportation and other infrastructure, presents big burdens and challenges with which countries, cities and local governments, but also citizens are faced. The negative effects of traffic are visible on a global and local levels. One of the ways we can combat this is to find solutions and develop sustainable mobility in the transport infrastructure.

Sustainable urban mobility can be defined as "*the ability to meet the needs of society to move freely, gain access, communicate, trade, and establish relationships without sacrificing other essential human or ecological values today or in the future*" [22]. Many authors have dealt with different aspects of sustainable urban mobility, focusing on environmental and social issues of transport in urban areas and their solutions [23,24]. The research identified non-motorized transport, land-use, and transport planning integration, technologies implementation, citizen participation, and short-distance urban planning as significant sustainability urban mobility strategies [25]. The path towards more sustainable mobility requires replacing conventional automotive technologies with zero- or low-emission vehicles to overcome the barriers to adopting new technologies through a joint effort between the public and private sectors [26]. Indicators for sustainable urban mobility are classified into several groups: integration of land and transport planning, accessibility, increased

[1] Of the 100 ARC3.2 cities, 45 had temperature data available for the 1961 to 2010 period. For each of these 45 cities, the trend was computed over the given period. For the trends, 39 cities saw significant (at the 99% significance level) warming. Data are from the NASA GISS GISTEMP dataset.
[2] Temperature and precipitation projections are based on 35 global climate models and 2 representative concentration pathways (RCP4.5 and RCP 8.5). Time slices are 30-year periods centered around the given decade (e.g., the 2050s is the period from 2040 to 2069). Projections are relative to the 1971 to 2000 base period. For each of the 100 cities, the low estimate (10th percentile) and high estimate (90th percentile) were calculated. The range of values presented is the average across all 100 cities.

mobility, promotion of non-motorized mains, encouragement of public transport, environmental concerns, economic welfare, and road safety [27].

To achieve sustainable urban mobility, it is necessary to systematically develop and implement appropriate planning strategies and tools for improving transport at local, regional, and national levels following needs and specific challenges. Sustainable Urban Mobility Plan represents a concept established to be developed first in Europe, then also internationally, as a strategy designed to satisfy the needs of people and businesses in mobility for higher living standards. The Plan is based on the following principles [28]: 1) plan for sustainable mobility in the functional urban areas; 2) cooperate across institutional boundaries; 3) involve citizens and stakeholders; assess current and future performance; 4) define a long-term vision and a clear implementation plan; 5) develop all transport modes in an integrated manner; 6) arrange for monitoring and evaluation; 7) assure quality.

Sustainable Urban Mobility Plan (SUMP) aims to create an urban transport system with the following objectives as well to reduce air and noise pollution, GHG emissions, and energy consumption [29]. Also, it must be followed with adequate action plans to provide a detailed explanation of the measures toward reaching urban mobility. Policies and measures of sustainable urban mobility are defined by the Plan and cover all types of transport in the urban matrix, including public and private, passenger and freight, motorized and non-motorized, moving, and parking. For such a Plan to be further developed and applied, an integral approach and coordination at various levels of local and state government are necessary. Figure 2 shows the main characteristics of Sustainable Urban Mobility Plan as a circular process.

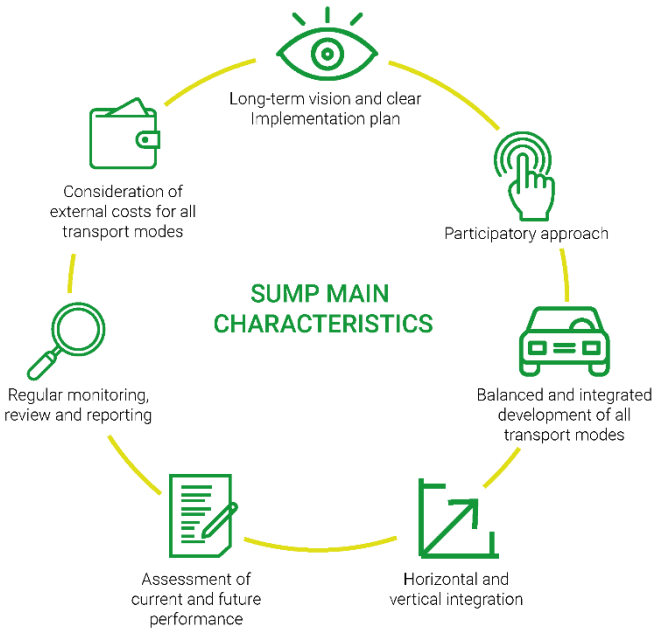

Figure 2: SUMP main characteristics [30]

3.2 Electric vehicles and sustainable urban mobility

At the global level, the number of electric vehicles is still not large, and they are not competitive enough in the market due to many problems accompanying the development of this industry. The high price of vehicles, insufficiently developed infrastructure that has to keep up with the increased number of vehicles, and often unresolved technical details, are just some of the problems faced by manufacturers and users. However, many studies show that electric vehicles can bring revolutionary changes to the automotive industry [31,32]. For electric cars to be sustainable, they must use energy from renewable energy sources.

If sustainable urban mobility were based on shared and electric vehicles, CO_2 emissions from traffic could fall by 60% [9]. Energy efficiency in internal combustion vehicles has been shown to reach only 15%. In other words, around 85% of the energy required to move a vehicle is lost. This is because the energy is transformed and evaporated during fuel production and logistics: refining, transport, loading, and unloading of the product to the gas station, pouring it into the car. A similar

loss occurs during combustion inside the vehicle's engine. Electric vehicles, in contrast, with no combustion process and an energy matrix composition with a high NCRE index, can perform with an efficiency of close to 80%. Greater efficiency, however, is not of much use if these savings cannot be fed into the electrical grid to create additional benefits for drivers and the system as a whole [26].

3.3 Importance of RES for sustainable urban mobility

Transport accounts for over a third of global energy use in cities today, and IRENA's Roadmap for a Renewable Energy Future (REmap), suggests this could grow by nearly 50% by 2030 [33]. If the energy demand is met by fossil fuels, it will have major consequences for air and noise pollution in cities and for global warming. For road, the main options are electric vehicles, biofuels (both liquid and gaseous) and hydrogen (when produced from renewable power). As with buildings electrification, transport can drive the uptake of renewable energy.

Cars in cities rely mostly on fossil fuels. Electrification of motor vehicles is an important option for urban mobility decarbonization. The number of electric cars in cities remains marginal. To have any impact on CO_2 emissions their use must increase rapidly, as electric vehicles are becoming more affordable. Policymakers can accelerate their adoption with a wide range of incentives. To achieve cities' decarbonization motor vehicles with zero emission of harmful gases must be used.

Their batteries are feeding their surplus energy into the grid during high-demand hours and could replace energy from other more polluting, more expensive sources. With the development and the improved competitiveness of unconventional renewable energy (NCRE) sources, such as wind or solar power [26]. The advent of electric mobility and the increasing use of such vehicles may bring about associated benefits that transcend the transport sector. While this will not solve congestion problems, it focuses on the decarbonization of the sector, which currently demands around 70% of energy from fossil fuels, according to the International Energy Agency (IAE) [34].

The future of transport systems lies in the application of renewable energy sources (RES). They are environmentally friendly, has a positive effect on addressing climate change, and reduce air pollution. Solar and wind energy can be used to power transport systems such as electric vehicles, aircraft, ships, buses, and trains [21]. A sustainable transportation system powered by RES is a necessary condition for preserving the planet. Still, several obstacles must be overcome. RES is not constant, they depend on the time of day, time of year, location, and geographical conditions. The next problem is the price of RES for road infrastructure, retrofitting vehicles with these systems, etc. Third, the development of RES for transportation is burdened by the prohibitive costs of battery chargers. In addition, the problem is the limited distance that electric vehicles can travel before they need to be recharged. The transition requires large initial investments. All these issues are very complex and cannot be solved quickly and simply.

4 Possibilities of developing new technologies in traffic and Smart City concept

4.1 Impact of new technologies on urban development

The implementation of ICTs in the last two decades has caused a revolution in cities' transformation into the so-called Smart Cities. New technologies increase the quality of life, management, and access to a wide specter of data and provide solutions to different functions and issues of a contemporary city, such as more efficient mobility and reduction of traffic jams, creating a healthier environment by reducing pollution. An important segment in new technologies implementation is the ICT infrastructure that will enable the transfer of big data allowing communication between different services and users (smart mobility infrastructure). Solving the problems of GHG emissions, infrastructure systems, and transportation, is based on available technologies and mutual connections between the complex information, communications, and regulations systems. In addition, the possibilities for reducing energy consumption include the smart technology’s introduction, through energy-efficient city transportation, traffic monitoring and signal control systems across the city [7].

4.2 Smart City and smart mobility

Cities are hubs of economic, political, and cultural activities and centers of knowledge and innovations. With their means and capacities, they have the leading role in the development and implementation of measures for increasing energy efficiency (EE) and the use of renewable energy sources (RES). Advocating for smart cities, which also implies new technologies and infrastructure, has a deep foundation in science and practice [35]. The Smart City will be integrated with mobility solutions based on efficient use of energy, electric vehicles, and shared resources with a high level of infrastructure integration among citizens. Cities will be planned to accommodate their citizens closer to work and recreation. None of this can be achieved without a significant focus on the design, planning, and delivery of urban infrastructure that enables massive improvements in urban mobility [36].

The Smart City concept has developed as a product of the Fourth Industrial Revolution and comprehensive digitization that has affected all aspects of urban life. The transformation of cities into smart environments aims to improve people's quality of life and the infrastructure system and simplify citizens' activities [37]. The most obvious changes in the urban areas of developed countries in the context of the application of smart technologies are visible in the urban mobility sector. Given that the concept of a Smart City aims for sustainable environments through the application of technologies recently the term Smart Mobility has been increasingly encountered in the literature [38,39]. Integrating ICT infrastructure into all traffic segments using big data, cloud services, internet of things (IoT) platforms, and sensors significantly improves the transport system while regulating traffic jams and favoring pedestrian and bicycle traffic [40]. According to Gifinger (2007), Smart Mobility implies good accessibility to the city, innovative non-motorized transport, and the implementation of technologies [2].

The primary goal in creating sustainable urban mobility is the transition from private vehicles to public transport [40]. Further, in the cities, there is the possibility of renting bicycles and cars. Smart mobility is recognized in developed urban areas through:

1) Use of electric vehicles - cars, trams, buses;

2) Urban design that promotes pedestrian movement and bicycle traffic, especially in central city areas, near residential areas, and recreation and sports zones, to reduce the use of motor vehicles;

3) The use of sensors for locating public city transport and notifying passengers, thereby reducing waiting time;

4) Electronic toll payment;

5) Use of sensors to inform traffic passengers about free parking spaces or traffic jams;

6) Creation of IoT platforms for rental cars and bicycles.

Figure 3 shows the three main factors and their effect on mobility sector and number of vehicles regarding digitalization: use of electric technologies, automation and use of shared internet platforms.

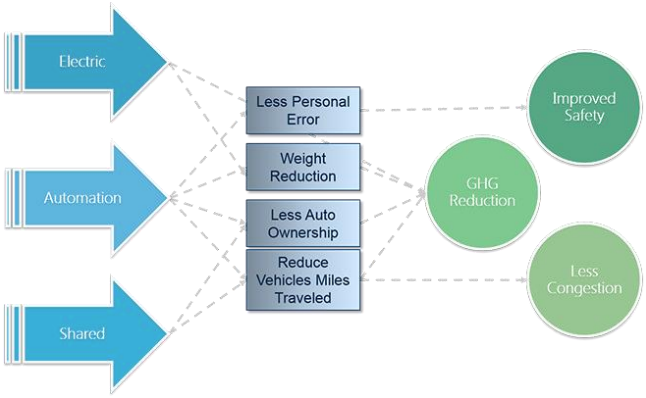

Figure 3: Smart Mobility using technologies [41]

5 Conclusion

Sustainable urban mobility is an issue in the contemporary world that incorporates various influences and has a connection to wider problems that surround the growing world and especially the urban population. As the population grows so do its needs such as transportation (individual and collective), energy dependency, increased built urban area, etc. Such needs later produce multiple problems including CO_2 pollution from extensive traffic, less green areas replaced with urban areas or traffic communications, etc. Interdependence of transportation to almost all other urban development aspects in the urban areas results in an immerse increase in energy needs, pollution, non-efficient use of resources, and fewer long-term benefits (on basis of short-term needs).

For an urban area to be properly managed it needs to have incorporated sustainable urban mobility as part of a successful urban economy with a multidisciplinary approach and the participation of experts of various profiles. Addressing urban mobility halfway is also an ongoing problem, as seen in terms of transportation and electric vehicles that although representing progress including the reduction of CO_2 emissions, often do not have enough sustainable resources for their electricity needs. Mostly fast-growing needs for more resources in urban areas and transportation outshine the amount of sustainability with which these needs are met.

On the other hand, more and more cities in the world are advocating for sustainable urban mobility with RES, that improves and changes the way and quality of life, noting that future research should not only focus on technical aspects but also on the broader political, economic, and social contexts in which these technologies are adopted. The application of RES makes cities greener, healthier, and more energy efficient, with a sustainable and clean source of fuel that is used from natural resources. The importance of using renewable energy in transportation can significantly reduce the carbon footprint with studies showing that the cities that have introduced RES and green mobility systems have reduced health problems of its citizens, such as respiratory diseases and heart diseases, and the injuries caused by traffic accidents are less likely to occur.

To effectively solve numerous health, environmental, climate, and other similar problems, we need to make sustainable urban mobility not just part of specific projects, and initiatives but have the wider approach in 1) legislative documents - through urban plans and strategies especially Sustainable Urban Mobility Plan, 2) through urban, transportation and other architectural (and construction) projects, 3) smart city services, and 4) overall public participation.

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