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Sustainable and Innovative Mobility in Megacities

by

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Abstract

One of the greatest challenges we face today lies in sustainable and innovative mobility. People require a seemingly endless network of vehicles and transportation systems. Sustainable urban mobility requires a mind shift: where transport in private cars and trucking give way to different modes of public transport. Like bicycle and pedestrian lanes, electric vehicles, car sharing. Cities all over the world are rising to meet the challenge. The above fact has motivated the current study, having as main goal to provide a literature review of the topic, investigating the current situation in eight megacities around the world, those of Istanbul, Tokyo, London, Sao Paulo, New Delhi, Cairo, Shanghai and Chongqing. Comparative analysis is adopted as a methodological tool, taking into account a wide range of aspects within sustainable mobility and using Deloitte's city mobility index as metric. The results show that each one of the megacities differs in terms of the adoption of sustainable development measures for their urban mobility. The level of integration of these measures varies due to several factors, such as the economic and technological development of each one of them as well as their social background. Although, all eight cities "realize" the importance of transition and adopt policies in that particular direction, they still have a long way to go so as to guarantee the maximum benefits

Keywords: Mobility, Sustainability, Megacities, MaaS, Safety

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Abbreviations

B.E.Vs……..…….Battery Electric Vehicles

B.R.T……..…Bus Rapid Transit

E.I.T……European Institute of Innovation and Technology

E.U……...European Union

G.C.R……..……..…. Greater Cairo Region

I.T.M.P……. Istanbul Metropolitan Municipality Transportation Master Plan

I.M.M……Istanbul Metropolitan Municipality

L.R.T…….…..…Light Rail Transit

MaaS……..……..Mobility as a Service

R4E……. Roadmaps for Energy

S.U.I.CA……. Super Urban Intelligent Card

S.U.M……Sustainable Urban Mobility

S.P.M.R…….…… São Paulo Metropolitan Region

T.E.M…….Trans-European Motorways

TfL…….……Transport for London

T.N.Cs…….…….Transport Network Companies

T.O.D……...Transit Oriented Development

Chapter 1: Introduction

1.1 Introduction

The ever-increasing importance of sustainability has turned the attention of the academic community to this field of study, which not several years before was more a subordinate task than a main priority.

Transport systems were considered the driving forces of economic and social development throughout the twentieth century (Gudmundsson et al., 2016). However, there has been a growing awareness of the negative impacts of transport activities, such as traffic congestion, fatalities and injuries, environmental pollution and energy consumption. (Moradi & Vagnoni, 2018). Urban transport activities are a major contributor to those negative impacts, particularly in megacities where the motorization levels are high, and automobile-dependence is the dominant mode of individual travel. 25% of the CO2 transport emissions are estimated to be caused by urban transport, of which 58% can be attributed to passenger transport (EEA, 2013).

The great impact of urban growth on transportation in megacities has become a major problem in the context of global climate change, as long as motorized mobility is a main source of domestic greenhouse gas emissions. Therefore, the transition to sustainable urban mobility (SUM) future (Banister, 2008) plays a central and vital role in achieving sustainable urban development aims (Banister, 2005).

The above fact has motivated the current study, having as main goal to provide a literature review of the topic, investigating the current situation in various megacities around the world, those of Istanbul, Tokyo, London, Sao Paulo, Cairo, Shanghai, New Delhi and Chongqing. The research questions are formed as following:

1. Which is the current situation in modern megacities in terms of innovative mobility?
2. How do the modern megacities reform their strategies so as to align with the ever-changing environment?
3. How do we rate Istanbul's action plan in the field of innovative mobility?

1.2 Structure of Thesis

The rest of the study is structured as follows: Chapter 1 is introductive giving a general insight about sustainable mobility. Chapter 2 provides the literature review for sustainability, mobility, innovative and sustainable mobility and the impact of Covid-19. Chapter 3 represents the research methodology that has been followed, while in Chapter 4 the results of our research regarding sustainable mobility -around the global megacities- will be examined. At the end of this chapter there will be a discussion on the aforementioned issues. Chapter 5 summarizes the conclusion of the study and provides topics for further research in the current field.

Chapter 2: Literature Review

2.1 Introduction

The current chapter is dedicated to a robust theoretical framework around the concepts of sustainability and mobility, so as to prepare the reader for the further analysis.

2.1.1 Sustainability

Not so many decades ago, sustainability seemed to be more a subordinate task than a vital issue for the planet. Yet, in the 21st century it emerges as a main priority. Climate change and increased energy demand lead to this fact.

Despite the extended academic literature on this field of study there is no common acceptable definition.

Being sustainable means to "keep going in the current stage also in the future" suggests Maude (Maude, 2014), while Ahern recognizes a much complicated nature of the term, related with a wide range of economic, social and environmental aspects. These three pillars of sustainability are given in the following figure (Ahern, 2015).

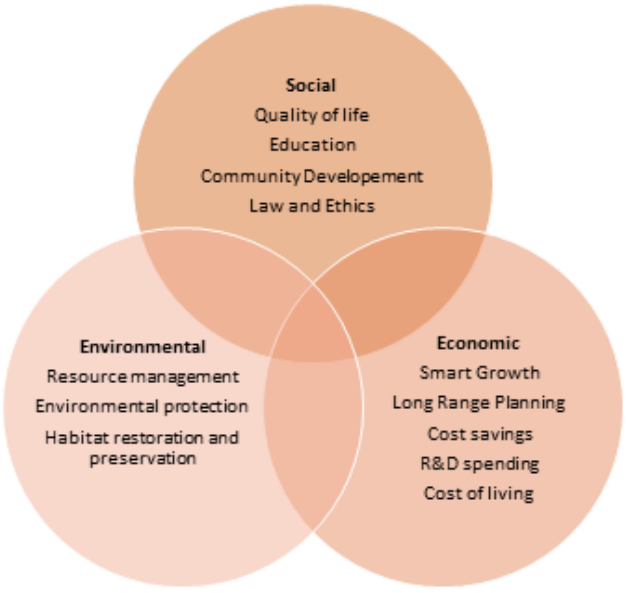

Figure 1: Three pillars of sustainability (Ahern, 2015)

A balance between these three aspects of sustainability is sought so as to guarantee the maximization of respective benefits.

In its Agenda for Development, U.N. defines that: “development is a multidimensional undertaking to achieve a higher quality of life for all people. Economic development, social development and environmental protection are interdependent and mutually reinforcing components of sustainable development”.

Generally, sustainable systems are divided in four categories (Sikdar, 2003):

1. The first category refers to global problems such as climate change, global warming, ozone depletion, greenhouse gases etc. So as to cope with these phenomena collective actions are needed.
2. The second one refers to much more eliminated systems in terms of geographical boundaries, such as cities. These systems contain a wide range of technical disciplines, among them urban planning, civil engineering and hydrology, including both economic and environmental goals.
3. Economic entities constitute the third type of sustainable systems. Besides, businesses and organizations tend to prioritize vital aspects of sustainability like clean technology, recycling, waste management etc.
4. The smallest of all systems are included in the fourth category, which is focused on “sustainable technologies”.

2.1.2 Mobility

Mobility management arises as a vital part of every sustainable strategy, representing a wide range of social and economic affections as well. Annual passenger traffic will approach 80 trillion passengers per kilometer by 2030, with global freight volumes increasing by 70%. By 2050, there will be 1.2 billion more cars on the road than there are now. To accommodate this increased demand, transportation infrastructure and services will play an increasingly important role.

The importance of transportation in terms of economic development and human capital cannot be overstated. Transport shapes our lifestyles and underpins everything that we do—the way people travel to work or leisure, how firms ship products to distribution

centers. Infrastructure solutions and transport services combined with land use determine accessibility. Access to public transportation is frequently distributed unevenly across locations. Rail and bus service capacity and quality are often missing from impoverished areas. Likewise, private-vehicle-oriented transport undermine the development of walking and cycling infrastructure (Sustainable Mobility for All, 2017). Mobility is essential to our survival and well-being. However, the global mobility system seems to be unsustainable. It is linked to extensive fossil-fuel consumption, high greenhouse-gas emissions, air and noise pollution, environmental deterioration, traffic accidents and deaths, and the economic isolation of rural people and impoverished urban dwellers. Getting the transportation system to be sustainable has become a defining component of society's future in a world that is becoming increasingly wealthier and aiming for more mobility (Sustainable Mobility for All, 2019).

2.1.3 Innovative mobility

Innovative mobility is not necessarily based on new technological approaches. Innovation may be either a product, a process or a combination of the two (Edwards-Schachter & Wallace, 2017, Gault, 2020). It could be a new mobility offer (e.g. a new carsharing programme), or a social or institutional process that results in the identification or application of a new mobility approach (e.g. a social innovation). A well-established mobility solution may be considered innovative if it is novel in the particular context in which it is being applied. It is important to recognise that no single innovation provides all the answers and different approaches are suited to different territorial, demographic and governance contexts (Randall, et al., 2020).

Innovation commonly links to urban issues through ‘smart cities.’ This definition is based on communication technologies for the transformation and improvement of availability and quality of infrastructure and services, minimizing the gap between government and citizens and between the standards of organization, learning, and management of infrastructures for all actors, with sustainable development as a background (Lima, et al., 2020).

Because the term "smart city" is broad and describes various perspectives (environmental, social and economic) there is no consensus on the principles that should be followed in the development of smarter and more sustainable communities (Guedes, et al., 2018). The need to improve citizen quality of life has an impact not only restricted to environmental sustainability goals but also to people's well-being. This in turn is linked to sustainable urban mobility, the promotion of active mobility, and the connection of these transport modes to the use of public transport. In this context, ‘smart’ and ‘sustainable’ must be strongly connected, both being targets of the same paradigm shift (Lyons, 2018).

2.1.4 Sustainable mobility

Sustainable development is about “meeting the needs of the present without compromising the ability of future generations to meet their own needs” (WCED, 1987).

In recent years, much progress has been made to address mobility in urban areas. Sustainable urban mobility includes walkable and bikeable cities, inclusive transport infrastructure, access to public transit, car-sharing systems, and autonomous (electric) vehicles. The main issue is to reduce the use of private automobiles in cities without compromising access to mobility (Schröder, et al., 2019).

Sustainable urban mobility approach underlines the importance of an integrated set of actions combining several policy areas such as land use, health, environment and social services.

To achieve the objectives of sustainable urban mobility, several policies and actions should be implemented. Restricting car use, promoting public transport, cycling, walking and encouraging land-use policies for compact and mixed use development, are the main policies adopted by the cities (Buehler et al., 2017). However, realizing those policies depend on the contextual factors that differ from city to city.

2.1.5 Shared mobility

Various regions of the world have begun to transform as a result of recent technological developments and implementations. The idea of smart transportation and mobility is a specific field that has been adopted among different areas around the world that are

concerned with creating intelligent and efficient environments. Despite its power and potential, sustainable mobility still faces a number of demographic and environmental issues.

Shared mobility is the shared use of a vehicle, motorcycle, scooter, bicycle, or other travel mode. Shared mobility provides users with short-term access to one of these modes of travel as they are needed (Shared Mobility, SAE International). While public transport remains a basic form of shared mobility, new models based on shared use or ownership of automobiles are gaining ground thanks to digital platforms and a shift toward a sharing economy in other industries (Transport, www.gov.uk/dft, 2019).

2.1.6 Mobility as a Service

Mobility as a Service (MaaS) is a very recent concept that is gaining ground in both the scientific and the private sector. While a universal definition has yet to be developed, in the most prevalent view, it describes a new transport solution that integrates public and private transport services from different transport operators and service providers on a single platform (P. Jittrapirom, et al., 2017). Field trials – essentially conducted in developed countries – prove that MaaS can have a great impact on people's mobility behavior and can create more efficient and sustainable transport systems for the future. For example, during a 6-month MaaS field trial in Sweden, it has been found that "over time the participants became less positive towards private car and more positive towards alternative modes" (I.M. Karlsson, et al., 2016).

With regards to implementing MaaS in developing cities, the translation of transport policies settings – especially from a developed to a developing context – remains a difficult task (Canitez, 2020). Rather than policy transfer, putting the acquired knowledge into practice and implementing it locally is the critical step (Pojani, et al., 2020). This would require the consideration of local socio-cultural heritage, traditions and citizens' preferences, amongst others (Fariya Sharmeen, et al., 2021).

2.2 The impact of Covid-19

COVID19 and its political constraints had a huge impact on the mobility sector, with a significant decline in mobility behavior due to travel bans, lockdowns, and a diminished desire to be mobile, among other things. The reduced usage of public transportation led to increased usage of cars. Besides that, there was a relative in bike usage too. During pandemic people feel more safe to use bikes or walking, due to a smaller fear of infection (Kanda & Kivinmaa, 2020).

The most significant change in the transportation sector was the reduction in travel mobility, particularly in aviation. In mid-April 2020, global commercial aviation activity was 75% lower than the annual average from 2019 (Abu-Rayash & Dincer, 2020).

According to Le Quéré et al., restrictions in mobility during the first two months of the pandemic resulted in a 17% reduction in global CO2 emissions. On the other hand, aviation-related emissions reduced by 60%, contributing to a 10% reduction in worldwide emissions (Le Quere et al., 2020).

Despite the fact that the automobile and mobility industries were among the hardest hit by the COVID-19 pandemic, mobility has lately returned to pre-crisis levels in many parts of the world. These years have been marked by uncertainty for not just end users but also individual businesses, mostly due to a supply-chain challenge unseen in the recent years. Furthermore, the whole supply chain's sustainability and decarbonisation need a considerable redesign of existing industry procedures and structures (McKinsey & Company, 2021).

While overall mobility is improving, not all forms of transportation have recovered to their pre-COVID-19 levels in all locations. The use of shared-mobility services and public transportation is increasing over the world, but in areas where commuters continue to work from home, the recovery is taking longer. The following are some of the significant findings from the global mobility survey about consumer behavior:

- About 51 percent of global respondents said that they intend to travel less than they did before the pandemic. However, mobility is increasing gradually and at different rates in certain areas, with the fastest recovery occurring in the United States.

- The regular use of public transport has picked up significantly compared with late 2020. Shared modes of transport (especially micromobility services) are now above pre-COVID-19 levels.
- Public transport and shared-mobility modes are considered more or less safe again with regard to COVID-19 infection.
- The frequency of commuting trips is recovering at different rates. Around the world, expectations differ about commuting patterns and workplace scenarios in the next normal.

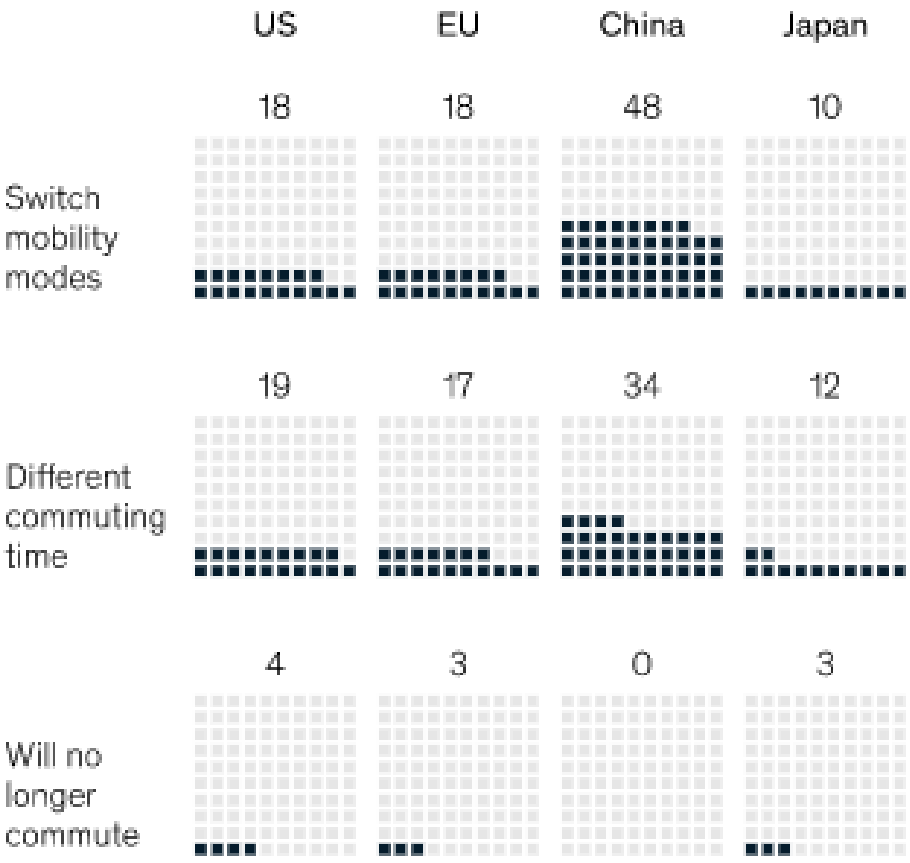

Figure 2: Expected commuting habits, post Covid-19, % of respondents (McKinsey Global, 2021)

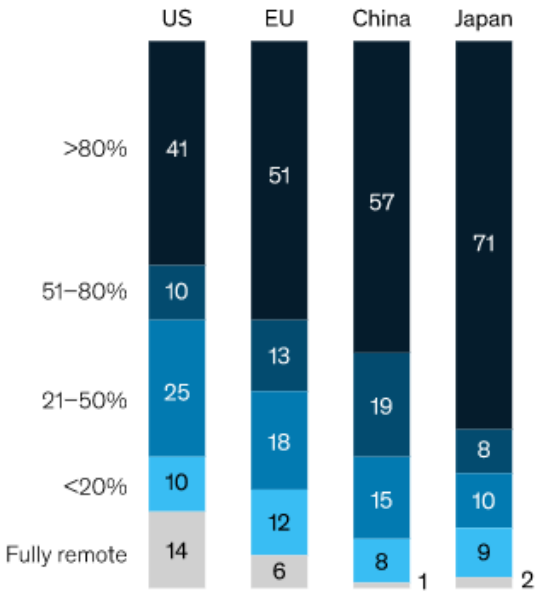

Figure 3: Expected share of time spent at workplace, post Covid-19 (McKinsey Global, 2021)

Apart from the direct impacts, the pandemic affected people's daily transport choices. For many people around the world, private transportation has been the favored means of transportation since the beginning of the pandemic. However, shared modes of transportation have regained market share. For example, as many cities throughout the world have expanded their efforts to limit the number of vehicles, micromobility options—both shared and owned smaller vehicles—have recently grown more popular. (McKinsey & Company, 2021).

People can actively contribute to the major change toward sustainability by changing their consumption or lifestyle habits. In some respects, the COVID-19 lockdowns appear to be accelerating changes that were already being contemplated, such as making city centers friendlier for pedestrians and cyclists. Cities that are looking to provide clear space for cycling and walking instead of street space for cars, are those which will make the difference in the post-coronavirus era.

However, it's difficult to say with certainty which changes will be temporary and which will be permanent. The combined effects of the pandemic and the probable economic fallout may be enough to erase the trends of the previous decade. Nevertheless, this crisis may help cities move toward a future of cleaner, safer, faster, more equal, and accessible mobility.

Reliable, accessible, and affordable transportation that minimizes environmental impacts is still a key necessity. Residents and policymakers around the world recognize that a well-functioning public transportation system, bike infrastructure, and new and shared modes of mobility are critical to their cities' economic viability (Bert et al., 2020)

Chapter 3: Methodology

3.1 Research Questions

The main goal of the research is to identify whether megacities are aligned with the ever increasing challenges in this field of study, as long as to investigate the future prospects, while the research questions are formed as following:

1. Which is the current situation in modern megacities in terms of innovative mobility?

2. How do the modern megacities reform their strategies so as to align with the ever-changing environment?

3. How do we rate Istanbul's action plan in the field of innovative mobility?

3.2 Suggested Methods

For the needs of the current study a mixture of comparative analysis and case study approach is adopted, using mainly secondary sources. Besides, mobility is an urgent topic in the related literature, especially during the last decade.

In particular, is attempted a systematic comparison of eight megacities, namely Tokyo, London, Sao Paulo, New Delhi, Cairo, Shanghai, Chongqing and Istanbul, in terms of the applied ones' practices, their condition, quality or other characteristics using a selected set of performance measures. This qualitative method let us conduct an in-depth analysis of sustainability and innovative mobility in megacities. Besides, such an approach enables the simultaneous analysis of multiple cases.

The city of Istanbul, embodying many of the features characterizing developing megacities having low or non-existent cycling modal shares, with a population of approximately 15 million people, is selected as a case study in order to investigate further aspects of innovative mobility.

First of all, the term of megacity is defined and a literature review is conducted so as to assess the current situation in megacities. Then, Istanbul is thoroughly analyzed in terms of sustainable mobility and then is compared to the other seven cities.

Chapter 4: Results

4.1 Introduction

As it has already been implied, innovative mobility is a quite complex task in the context of the ever-changing environment. Despite the fact that vehicles play an important role in most cities' transportation systems, a growing number of cities are looking into measures to limit their use and shift people away from private transportation. Some cities have put strict restrictions on cars because of their negative impact on the environment. At the same time, other cities have attempted to promote the use of alternative modes of transportation by improving public transportation (see the tram sidebar) and providing greater infrastructure for active modes of transportation. Around the world, 100 cities, have totally fare-free public transportation (Abigail, 2020) and many more are working to expand bike lanes (Connolly, 2020).

In general, there seem to be structural differences between megacities. Thus, so as to define the performance of modern megacities in this field, we have to take into account a wide range of characteristics, among them: congestion, transport reliability, transport safety, air quality, modal diversity etc.

The term megacity is not new. The role of megacities in economic development is undeniable, and so is their ever-increasing share in academic literature. According to the general consensus and following the UN population reports, a megacity is defined as “a metropolitan area with a total population in excess of ten million people’’ (Gerd A. et al., 2015). The massive migration from rural areas is one of the main drivers for the increasing number of megacities that, acting like spatial concentration points, contribute significantly to the increasing share of urban population and GDP to the country totals (Facchini, et al., 2017). In any case, megacities are defined by their population and thus, they should not be confused with world cities, which refer to the global function of the whole system.

In environmental terms, megacities are believed to be “inherently unsustainable with their vast consumption of resources drawn from distant elsewhere, and equally vast production of wastes that are routinely exported elsewhere” (Sorensen & Okata, 2011). Yet, despite the fact that smart megacity or sustainable megacity sounds to be an oxymoron, the related literature suggests a number of urban policies that may lead to much

better results. Besides, the ultimate goal is to form cities that guarantee sustainable development rather than cities that are sustainable per se.

Megacities have a variety of environmental impacts. In order to sustain themselves, and pursue business activities, such as manufacturing, people consume food and energy and produce waste in solid, liquid and gaseous form. Due to the high population density, food, raw materials and energy cannot always be produced locally. As a result, the transportation of goods and waste products in and out of cities has significant environmental consequences (Gerd A. et al., 2015).

With a rapidly increasing population of 15 million people, Istanbul is a good example of developing megacities, where rapid and unplanned urban growth and growing urban mobility problems present significant urban challenges. Chronic traffic congestion, overcrowded public transport services and environmental pollution are some of the urban mobility problems resulting from car-based urban development, insufficient public transport capacity, fragmented governance, policies and institutions.

4.2 Global megacities

Sustainable and innovative mobility in megacities is an urgent topic and has been extensively studied during the last decade.

A number of studies address urban mobility and transport from a transition theory perspective (te Brömmelstroet & Bertolini, 2011; Kohler, et al., 2009; Sheller, 2011; Zijlstra & Avelino, 2012). Developing megacities share some common characteristics and urban problems (Pojani & Stead, 2017): rapid urbanization, high population density, political and economic instability, weak institutional structures and urban governance, young and growing population, unemployment, and predominantly informal economies. Some examples of developing megacities around the world include Istanbul, Mexico City, Sao Paulo, Delhi, Jakarta, Shanghai, Manila, Lagos, Cairo and Bogota (Canitez F., 2019).

Developed cities generally have a transport authority which is responsible for the management and organization of the overall urban mobility. In contrast, developing cities have more fragmented governance structures (Canitez, 2019) and lack of financial, human,

and knowledge resources which hinder the effective implementation of transport policies (Pojani & Stead, 2017).

The mobility system does not operate on its own and is influenced by a variety of elements. Everyone uses transportation for a number of reasons, including commuting, tourism, business trips, and global or local trade. A range of transport services are used with distinct characteristics in terms of costs, speed, and reliability. Because of the close linkages between transportation and other systems, interactions between the two are complicated and unpredictable, including external influences (European Environment Agency, 2017).

The transition to sustainable mobility can only be successful if urban planning and transportation investments are well integrated, taking under consideration how crucial are the connections between transportation, land use, and socio-cultural contexts to developing effective mobility management campaigns (Hickman, Hall, & Banister, 2013).

Mobility is considered a critical factor in the field of inequalities in megacities as well. Chiquetto et al. explore the role of job proximity, adopting Sao Paulo as a case study. They claim that an increase in local job offers decreases the distance travelled by population, especially in suburbs, achieving both social and environmental goals. Thus, policy makers ought to take into account spatial planning of land use within transport planning in a megacity environment (Chiquetto et al., 2021).

The role of mobility in less motorized megacities is examined by Mohan et al., taking into account pollution and safety issues as well. Using Delhi as a case study, they claim that traffic patterns are quite complex. Public transport and para-transport already constitute a significant percent of total transportation, while, on the other hand, bicyclists and pedestrians seem to face much greater risks. Thus, increasing their share emerges as an extremely hard task. So as to achieve the current goal, it is vital to ensure both convenience and safety.

The crucial value of urban space, travel demand management, and the processes in urban mobility development are some of the primary outputs of the mobility culture study. In a bottom-up and top-down strategy, communities must design appropriate local strategies (Wulfhorst et al., 2013).

By developing a framework for "Transport Network Companies" in August 2015, the Philippines became the first country in Asia to allow app-based shared mobility services (TNCs). The fundamental principle was already culturally established, thanks to the country's long history of shared transportation. However, compared to the overall shared transportation market, the current market for TNC services is limited to a small segment of the population, given that only around 31% of Filipinos have bank accounts, with an estimated 4% having access to credit cards and a smartphone penetration of around 21%.

While it remains unclear whether TNC services will ultimately reduce car ownership by providing an alternative shared model, their rapid adoption and growth show that they are improving overall mobility for certain population segments. The services, however, remain out of reach for the majority of the people, resulting in increased mobility inequality. Both traffic congestion and access inequality are topics of discussion in developed countries, but they are amplified by the tremendous growth rates of cities like Manila, Jakarta, and Bangkok, where the future of such services will likely be defined and decided far ahead of the West by everyday practice (Schechtner & Hanson, 2017).

In the case of China, the management of forms of urban expansion on the outskirts of the city in order to create a sustainable transportation system is usually overlooked, despite growing interest in industrialized countries. Furthermore, while increased local government autonomy and economic accountability has fueled urban sprawl, the negative consequences of sprawling expansion on transportation show the government's failure to manage growth during the current transformation process. Stronger metropolitan development management measures should be implemented to limit local growth on the city outskirts and promote sustainable mobility in order to ensure sustainable urban expansion (Zhao, 2010).

Reddy & Balachandra conduct a comparative analysis among 23 Indian megacities, exploring three variables, namely: energy intensity, mode of transport and passenger kilometers traveled. Highlighting the risk of the increasing dependence on fossil fuels they promote a bunch of policies that combine cycling, walking and obviously public transport (Reddy & Balachandra, 2012).

Megacities face a variety of urban mobility challenges including energy scarcity and climate change, unprecedented urbanization and suburbanization, as well as local

issues such as social and spatial inequalities, traffic-related health effects, severe congestion, conflict over urban space, and complex regional governance tasks. The question is how megacities can solve these issues in order to construct well-functioning mobility systems, while also improving their liveability, economic performance and sustainability. Because every city is different and multifaceted, there is no one-size-fits-all answer. However, it is stated that the mobility culture notion helps us in navigating our way through this complexity and finding appropriate mobility solutions in each city.

4.2.1 London

London has established itself as a leader in innovation as it was one of the first cities in the world to introduce congestion pricing, which means paying a fee to access the city's central area. That scheme resulted in a significant reduction in the number of vehicles in the zone while at the same time has enabled the Transport for London (TfL) to repurpose roads for bus and bike lanes. TfL is responsible for running London’s mobility system such as the London Underground, London Overground and the Docklands Light Railway, as well as trams, buses, taxis, cycling and river fleet services for the city.

London’s mobility is based on a well-coordinated plan, which includes goals on lower emissions and air-quality improvements while promoting even more use of public transportation and active modes of transport such as walking and cycling. TfL is also a great example of a government body that successfully balances public transportation supply with competent regulation of private sector-led partnerships, that strive to give extra services in the name of broader system-wide objectives

The improved efficiency of London's transportation infrastructure has contributed significantly to the city's reduction in environmental emissions per capita (Greater London Authority: London, UK, 2015). The stability in car ownership and use in London over the last ten years has become known as the ‘peak car argument’ (DavidMetz, 2015) & (Phil Goodwin, Kurt Van DenderJoint , 2013). Despite the fact that car ownership is declining, alternatives to car use and ownership are growing (e.g., car sharing, bike sharing, and ride-sharing services).

Over the last few decades, the UK's transportation policy has undergone significant changes. Despite the fact that the relationship between travel demand and car ownership is

dependent on a variety of factors, including the size of the city, demographics, transportation costs, and the availability of alternative mobility options, there is substantial evidence that car ownership plays an intermediary role in the built environment and car use (Genevieve Giulianoa, Joyce Dargayb, 2006) & (Veronique Van Acker, Frank Witlox, 2010).

4.2.2 Tokyo

The Greater Tokyo area's public transportation system is one of the world's busiest and most sophisticated. Having overcrowded trains and a complicated rail network, the system is, somehow, a victim of its own success. There are more than 30 private companies operating above-ground trains, creating a complex management challenge (Deloitte Insights, 2019). Residents in the western part of Tokyo and rural communities in the wider region still rely on private cars because public transportation is less robust, which is likely to put pressure on Tokyo's aging population.

Tokyo was one of the first cities to introduce an integrated smart card system for public transportation. The SUICA card (Super Urban Intelligent Card) was established in 2001 and has since become one of Tokyo's most recognizable transportation systems. These cards are prepaid, rechargeable, and contactless and may be used to pay for fares on practically all forms of public transit, including trains, subways, buses, and taxis.

Tokyo's mobility story is built on a strong private sector-led vision and leadership, which is made possible by government support and a flexible regulatory environment. The city has supported collaboration with the private sector to create public-private consortia that can help create more cheap and user-friendly programs as long as pilot projects have helped introduce new technology (Deloitte, 2020)

Tokyo's public transportation system, which is the world's busiest with 3.5 billion passenger travels each year, is dependable but overcrowded. By improving bicycle infrastructure, developing innovative methods to alleviate peak-hour congestion, and introducing new micro-mobility options the problem can be minimized. Despite having two of the major manufacturers, the city's EV adoption has declned due to the high cost of owning a car and the lack of public charging infrastructure –which is a necessity in a city where 60% of population live in multi-occupancy buildings (Deloitte, 2020a).

4.2.3 Sao Paulo

Between 1970 and 1996, the São Paulo Metropolitan Region (SPMR) has experienced intense growth with the population of the country doubled, while the number of motorized vehicles on the road increased by six times. The region has established itself as the country's most important economic and political region. Despite that, it has faced increased transportation issues, which are divided among socioeconomic groups and classes, taking into account those who have and do not have access to private transportation. The majority of the issues stem from a dramatic increase in the usage of private vehicles and a corresponding decrease in the use of public transportation.

Some of the consequences are high levels of air pollution, severe traffic congestion and a record number of traffic fatalities. Current issues are posing a threat to the region's economic efficiency and have also caused alternative transportation solutions.

The history of the Sao Paulo metropolitan area shows a set of policies that led the region towards unsustainability. The reason for that is the institutional conflicts about transport, traffic and land use. Until 1993, the federal railway company controlled a large portion of the suburban railway system. The coordination of federal and state railway systems has been hampered by differences in objectives and goals, as well as political and corporate rivalries. The bad services brought chaos to the system and as a result, people rejected the suburban trains in the country.

Apart from the federal system, there was a historic gap between metropolitan and local transportation policies. Within the metropolitan region, the State Department of Metropolitan Transportation was in charge of the subway system, the suburban railway, and all intercity bus services. However, mayors may protect their legal power to make decisions on local problems regarding regional transportation infrastructure.

In the city of São Paulo, urban and transport issues are handled by three different departments that works seperately: Transportation (SMT), Roadways (SVP) and Urban Planning (SEMPLA). This separation led to permanent uncoordinated policies regarding public transportation and traffic.

Public transportation systems suffered from significant supply and quality issues, which, along with rising fares and lower incomes for the poor, resulted in the exclusion of a huge proportion of customers. Moreover, negative externalities associated with increased automobile use, such as traffic accidents, congestion and pollution, threaten the sustainability of the city (Vasconcellos, 2005).

Lack of a comprehensive development plan, insufficient investment due to frequent economic shocks, and inequitable coverage have all harmed the city's transportation infrastructure. Yet, thanks to the support of the donor community, the city has expanded its urban rail network – albeit slowly. Attention needs to be given to the bus network, which covers a wider area with about 9 million passenger journeys each day, twice as many as the train network (Deloitte, 2020b).

4.2.4 New Delhi

India is going through a mobility transformation. This shift is most noticeable in cities, where increased demand for mobility services is forcing governments and industry leaders to rethink how to provide it. In this shift, Delhi has a vital role to play. A variety of progressive mobility solutions have been adopted in Delhi. In the early 2000s, the city converted its entire public transportation fleet—including buses, taxis, and auto rickshaws—on compressed natural gas (CNG) to solve the problem of pollution caused by vehicular emissions (Hindustan Times, 2018).

Delhi currently has one of the largest CNG-powered bus fleets in the world, serving about 27% of the city's journeys. Since the first corridor opened in 2002, the city's metro-rail network has grown to 373 kilometers (km) (Dialogue and Development Commission of Delhi, 2019). The metro carries over 3 million passengers per day, accounting for around 3% of all travels in the city. The Government of the National Capital Territory of Delhi proposed its first Green Budget in the 2018–2019 budget (AAM Admi Party, 2018) to fund long-term initiatives that mitigate rising levels of air pollution (The Times of India, 2018). Delhi’s draft EV policy aims to promote car electrification in order to combat the city's rising pollution levels. To support the objective of improving Delhi’s air quality, the draft EV policy sets an ambitious target for Battery Electric Vehicles (BEVs) to make up 25 percent of new vehicle registrations by 2023. The policy takes a comprehensive, system-level approach to vehicle electrification and offers fiscal and non-fiscal incentives to promote EV adoption in the city. The draft strategy proposes interventions to help two-wheelers, auto rickshaws, good carriers, and buses become

electrified. It commits to an ambitious target of a 25 % share of BEVs in new vehicle registrations by 2023 (Transport Department, GNCTD, 2018).

4.2.5 Cairo

In recent years, Cairo has experienced substantial urbanization and suburbanization. As a result of this expansion, and the incapability to expand the mass transit networks at the same pace, the satellite cities are found to be more car-dependent than the rest of the city. In these cities, both the capacity and coverage of public transit networks are restricted. As a result, most places in those new urban settlements found it difficult to access those mass transit systems. So, it pushes them to rely on private alternatives, which has negative consequences in increasing commuting fuel consumption, cost, and environmental pollution. New Cairo is highly dependent on private car usage (Hussin, et al., 2021). 74% of the population uses the car as the main mobility mode. This reliance, however, is not simply due to a lack of variety in New Cairo's public transportation systems. While New Cairo has a number of public transportation options, the majority of these options are trunk-network services that focus on connecting New Cairo to Greater Cairo Region (GCR) neighbourhoods without giving attention to intra-city mobility (Ghonimi & El Zamly, 2017). Old neighbourhoods, the grid street network pattern, high density with crowded streets make public transportation an inconvenient, unattractive, and uncomfortable mode of transportation for inhabitants. Modern neighbourhoods with low density, separate use, and large distance make public transit less feasible, resulting in an increase in private alternatives, which increases commuting fuel consumption, expense, and pollution. The overcrowded and low quality public mobility in old towns as well as new towns' low-feasibility public transportation and unsafe non-motorized mobility, are essential variables in determining movement behavior and minimizing their impact on achieving sustainable movement behavior and urban mobility. Different neighbourhood models can play a significant role in shaping individual travel behavior. Neighbourhood patterns impact the type, quality and quantity of mobility facilities that can be used and

accordingly shape residents travel choices of movement behaviour (Ghonimi & El Zamly, 2017).

4.2.6 Shanghai

Shanghai is characterised by its progressive development, high population density and high income, and is known as a Western-oriented ‘trendsetter’ city in China. Reducing carbon emissions has become China’s domestic target to address its many significant trends with its rapid economic growth, including industrial reform, minimizing overcapacity, environmental damage, and improved social well-being of its citizens (Liu, et al., 2013). With a population of 24 million people, transportation demand is a key indicator of the city's rapid and changing socioeconomic growth. Every year, there are 200,000 brand new private vehicles added to the road (ChinaNews, 2015). To address this issue, it’s China’s first town to apply car ownership regulations. It has a strong regulatory and prohibitive culture, limiting access to private car ownership and regulating the use of road infrastructure. Public transport is the backbone of transport in Shanghai and will be greatly extended in the coming years. The trend is already visible, indicating a shift toward reducing motorized traffic while at the same time enhancing multimodality and intermodality. According to Shanghai's most recent master plan, new main road construction projects will be phased out after 2020, consolidating public transportation's dominance. From now on, the degree of motorisation will not greatly rise. As a result, a gradual shift toward environmentally friendly modes of transportation will occur (Manz, et al., 2017).

4.2.7 Chongqing

Chongqing is challenged by heavy congestion, caused by the fact that the population density is particularly high in the core area as a result of the hilly topographical conditions. The restricted supply of public transport in the city leads to a high car ownership rate, as does the rapidly growing middle class and an economic policy geared to the internal

market and local production of vehicles (Manz, et al., 2017). In contrast to heavily regulated cities, metropolis's economic and financial policies are more oriented to local market, allowing an unrestricted admission of cars. Though there are access restrictions on using road infrastructures it is less prohibitive than many of the highly developed cities. The fast-growing city is experiencing an increase in mobility demand and rapid private motorization, which the city is now seeking to reduce with a car-sharing system.

Together with an international car manufacturer, Chongqing has rolled out the eco-friendly car-sharing system Car2Go. The system is free floating, with no fixed rental location and is the first of its kind in Asia. Car2Go shared vehicles help to reduce the car ownership in the city. The system allows the user to unlock the cars using an app and arriving at their destination they can park the car either in a public parking place or in one of the designated Car2Go parking spots (Global Opportunity Explorer, 2019).

4.3 Case study: Istanbul

Istanbul accommodates 15 million people and 14 million visitors per year (TSI, 2017) and is the most populous city of Eastern Mediterranean. The population density of Istanbul is given in the following map (Figure 4).

As a rapidly growing metropolis, Istanbul faces massive urban challenges. In line with the growth in Turkish economy and population, annual motorization rate increases by 4.5% per year (Netherlands Enterprise Agency, 2020). The number of cars has been increasing steadily and continuously over the years, with 15,800 new cars entering into road traffic per month. Almost 25% of vehicles in the country are registered in Istanbul.

Also, Istanbul comes first in terms of congestion between world's megacities as shown in Figure 6.

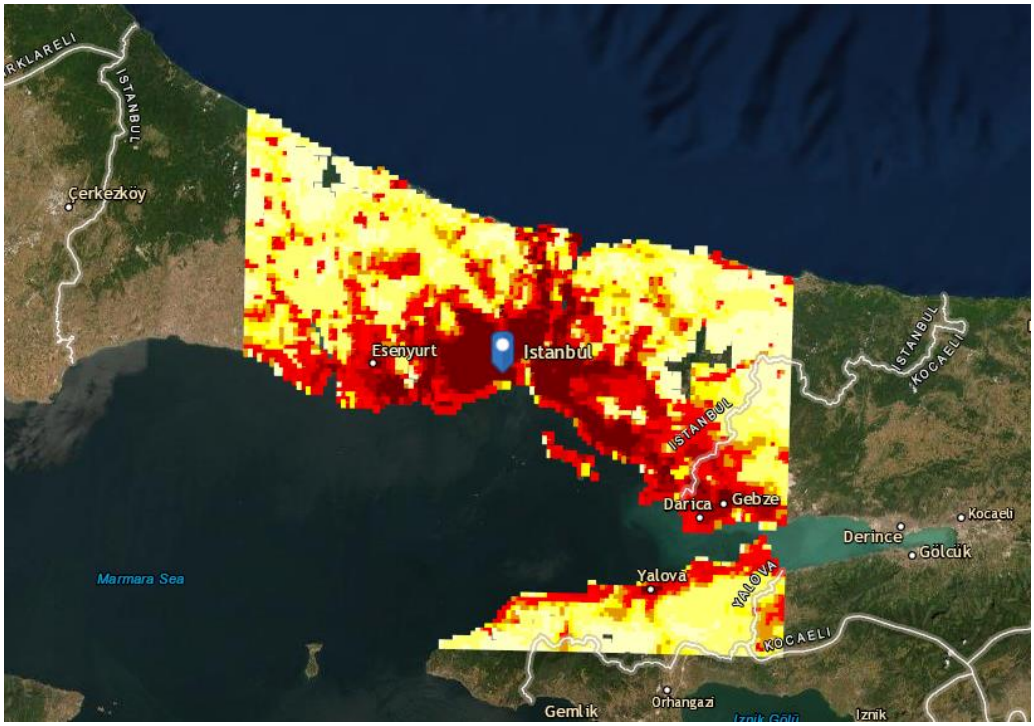

Figure 4: Population density map of Istanbul (https://www.arcgis.com/)

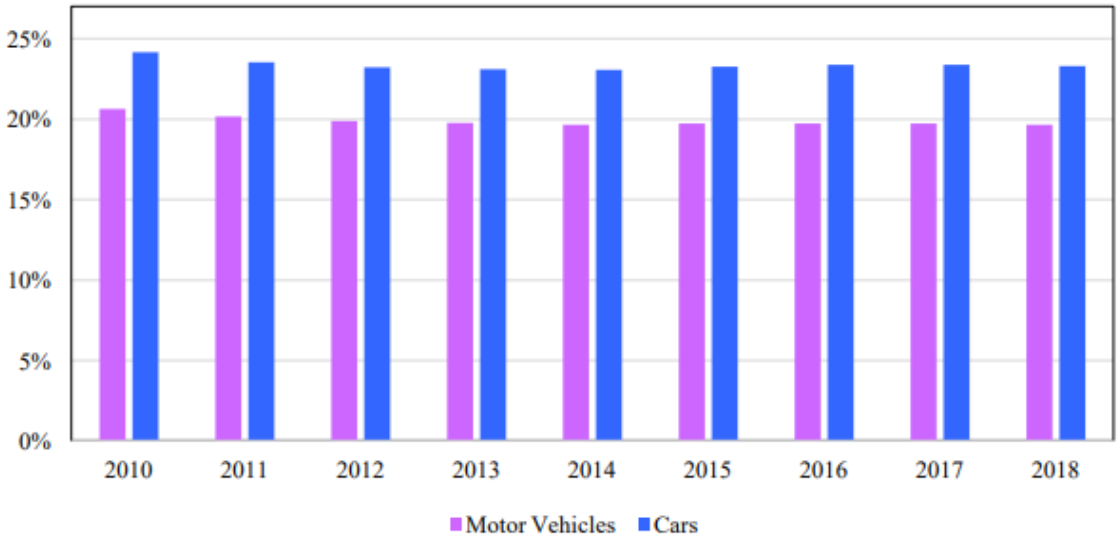

Figure 5: Ratio of all motor vehicles and automobiles in Turkey that are registered in Istanbul by year (Netherlands Enterprise Agency, 2020)

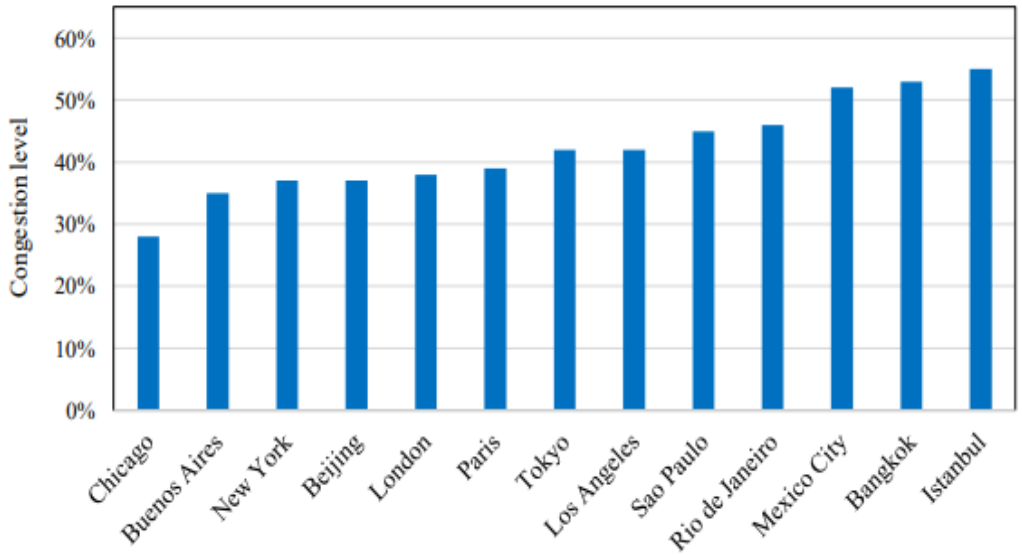

Figure 6: Congestion levels of megacities with more than 8 million inhabitants (Netherlands Enterprise Agency, 2020)

Chronic traffic congestion, inadequate and overcrowded public transport services, road accidents, noise, and environmental pollution are some of those problems which led the local government, Istanbul Metropolitan Municipality (IMM), to set out "Istanbul Integrated Urban Transport Master Plan" (IMM, 2011). In this plan, sustainability is adopted as a fundamental philosophy for managing the urban mobility, and cycling, albeit not considered a key component of the urban mobility, is supported as a transport mode. To date, a variety of infrastructure projects such as new bicycle paths, lanes, and parking areas as well as bicycle-share programs (ISBIKE) have been undertaken to introduce cycling; however, cycling has not become more than a leisure time and sports activity according to the assessments of the local government planners and experts.

An overall assessment of Istanbul's urban mobility policies is studied by Gerçek and Demir (2008), covering the institutional issues as well as mobility and land use patterns. So far, Istanbul has applied a wide range of actions so as to cope with the current problem:

- Istanbul Metropolitan Municipality Transportation Master Plan (ITMP) (2011)
- Istanbul Travel Surveys (2012)

- Assessing Istanbul's quality of urban life (2014)
- Istanbul Car Parking Master Plan (2016)
- Traffic Safety Master Plan (2016)
- Transit Fares Integration Model (2017)
- Taxi Management System (2017)
- Park Management System (2017)
- Digitalization Integration Model (2017)
- Istanbul Card Management System (2017)
- Congestion Charging Report (2017)
- Shared Mobility Model Development (2017)
- Integration Transport Planning (2017)
- Smart Transport Models (2017)
- The Information Integration System Model (2017)
- Transport Academy Study (2017)
- Istanbul Climate Action Plan (2018)
- Istanbul Development of Public Transport Strategies Master Plan Report (2019)
- IMM'S Strategic Plan
- Roadmaps for Energy (R4E)

4.3.1 Strategic Plan

The implementation of the sustainable transport concept is at the top of the new strategic plan's agenda. Increasing the capacity of mass transport services, decreasing automobile dependence, improvement and expansion of the road network, effective use of traffic management policies and increasing traffic safety are listed as the most important objectives of the new strategic plan. The expansion of the urban rail network has the strategic priority over the other capacity increase options. The aim is to make the rail

network as the backbone of the urban transport structure of Istanbul, with bus and minibus modes serving as the feeder lines for those metro and tram lines.

The below selected dimensions are based on the basic concepts of the Master Plan and the megaprojects in which the government has allocated more budget and effort recently.

1. Modal shift (balanced modal share)

Modal shift (balanced modal share) Istanbul's urban public transport system is composed of public transport services including public bus, bus rapid transit system, rail based modes, sea transport modes and paratransit modes together with the traffic management systems on the bridges, roads and streets. Despite the introduction of mass transit options, the shift from automobile to public transport has been limited. The modal share of rail-based transport within the public transport modes has increased from 24.8% to 32.6%. Rail-based urban transport modes including underground metro, Marmaray (the railway tunnel under Bosporus), tram, light rail transit (LRT), funicular and cable car have been increasingly becoming the backbone of the city's public transport system. The Master Plan promotes the expansion of rail network, thus addressing the urban transport challenges by providing reliable, safe and accessible transport services. Currently, 95.69 km of 5 metro lines together with 34.6 km of 2 tram lines serve more than 1.6 million passengers every day (Metro Istanbul, 2017).

2. Reducing road traffic and increasing the quality of public transport

Traffic congestion levels are one of the highest among the cities in the world, ranking as the 6th most congested city according to Tomtom traffic index (Tomtom, 2017). This policy is pursued with a policy of promoting alternatives to the car use by enhancing public transport, cycling and walking facilities. However, the conflict between those two opposing policies diminishes the impact of sustainability-oriented policy measures in Istanbul.

3. Megaprojects (urban sustainability implications)

Megaprojects are a major part of Istanbul's endeavor to improve the overall mobility of Istanbul. They are cherished by both local and national government as catalysts for the regeneration of Istanbul's not only urban but also intercity and international transport. The improved economic conditions as well as political support after 2000s facilitated the undertaking of megaprojects. However, megaprojects without considering sustainability

can bring about an excessive focus on economic growth, thus creates conflict, tension and inequality (Hannan & Sutherland, 2015).

The Bosporus Strait is the most critical urban formation affecting the urban mobility in Istanbul as well as the transnational and transcontinental transport (see Fig. 7). Most of the completed and ongoing megaprojects aim to facilitate the crossing over the Bosporus. Increasing the capacity of public transport (Marmaray) together with the road infrastructure (Eurasia Tunnel and the Third Bridge) is the main objective of those projects. They all contribute to the relief of traffic density on D100 highway, TEM motorway and the coastal road, together which constitute the main road arteries of the city. Rather than aiming to achieve a modal shift from automobile to sustainable transport modes such as public transport, walking and cycling, IMM aims to cater to the needs of public transport users and automobile users at the same time. Increasing the average speed of the traffic flow, especially over the Bosporus Bridges, is one of the strategic urban mobility aims of IMM.

There is a close and dynamic interplay among all the sustainability dimensions provided in previous section. Starting with the relationship between modal shift and megaprojects, megaprojects have contributed to the increase in motorized road transport and railway transport. For example, while Marmaray has become a key driver in increasing the sustainable mode share of Bosporus crossings, Eurasia Tunnel and Yavuz Sultan Selim Bridge have promoted the use of private auto mobiles.

Marmaray and new metro links can potentially incorporate the concept of Transit Oriented Development (TOD). The micro-level urban development around the major transport hubs is currently more market-driven without a Strategic Plan. The transit performance indicators (operating cost per passenger boarding, farebox revenue per operating cost, passenger boardings per revenue vehicle mile) are better achieved so as to justify the expected benefits of metro links, most of which are megaprojects in the case of Istanbul. The land use and transport integration (micro and macro level) is integral to pave the way for a more sustainable urban mobility in planning and implementation of mega urban projects.

The conflicting policy priorities of the Master Plan and Strategic Plan act as a major barrier in achieving a more sustainable urban mobility in Istanbul. Trying to accommodate both capacity increase in public transport and increasing car use through road infrastructure

and traffic management investments at the same time are not adequate to cope with growing urban transport problems. The projects and measures set out in the Master Plan and Strategic Plan require a comprehensive and holistic strategic approach. Sustainable urban mobility concept is not permeated through those projects and measures. Rather, the sustainability is itself regarded as a project separate from the general framework of urban transport strategies. This raises the concern that the discourse of sustainability is used as a rhetorical device in those plans, rather than an underlying and all-embracing policy. This is why the investments and projects implemented have not fully achieved the objective of a modal shift from car use to sustainable and active modes, including public transport, cycling and walking.

4.4 Discussion

As it is obvious, the world's cities are changing. New technologies and global sustainability goals are transforming the cities and how we move. Today's urban megacities face an array of challenges and they have to deal with, such as transformations to help create urban environments that consume fewer resources, contribute less to climate change, and support more liveable and healthy neighborhoods.

Each one of the megacities we have studied above, differs in terms of the adoption of sustainable development measures for their urban mobility. The level of integration of these measures varies due to several factors, such as the economic and technological development of each one of them as well as their social background.

Megacities seem to realize the importance of innovative mobility, although many of them still seem to be in very early stages. For example, Tokyo is a global leader in this field. In London many of the improvements to transport have been gradual and incremental, and focused on increasing the capacity of existing infrastructure to meet growing demand. Delhi and Sao Paulo, given their rapid economic growth, is on the rise. Cairo as a megacity is living the challenge of urban mobility due to the vast urban expansion and the population growth. On the other hand, urban residents of Chinese cities, like Shanghai and Chongqing, have developed a strong affinity for digitalisation, and are open-minded when it comes to testing new technologies, embracing a highly diverse mix

of all manner of vehicles and kinds of mobility. Last but not least, Istanbul in the context of its agenda, has a series of megaprojects to implement in order to turn to sustainable urban mobility.

Indicatively, in the appendix of this study, the comparison of 4 megacities is presented, based on some metrics. More specific Comparison is conducted in terms of City Mobility Index, as it is proposed by Deloitte. This index consists of fifteen metrics divided in three categories as follows:

1. *Performance and Resilience*: congestion, public transport reliability, transport safety, integrated mobility and modal diversity
2. *Vision and leadership*: vision and strategy, investment, innovation, regulatory environment framework and environmental sustainability initiatives
3. *Service and inclusion*: public transport density, transport affordability, air quality, customer satisfaction and accessibility

Chapter 5: Conclusion

5.1 Summary

Mobility is undergoing one of the most significant transformations in our generation, with far-reaching ramifications for how we live. The future of mobility being fuelled by three key technology-driven disruptive trends: electrification of vehicles, connected & autonomous vehicles and Mobility-as-a-Service.

Because of the improvements in regulatory policy, consumer attitudes, battery economics, and infrastructure, electric vehicles are approaching a tipping point, presenting opportunities for the automotive sector (Serruys, 2021). EVs accounted for only 6% of worldwide car sales in 2020, but that figure is expected to rise to 13% by 2025 and 22% by 2030. Stricter national emissions limits, rising urban populations, improved charging infrastructure, and the falling cost of the lithium-ion batteries that power EVs (down 80 percent since 2010) will all work together to boost widespread adoption of EVs over time (Marr, 2022). Belgium had the greatest result in the EU after Sweden in terms of newly registered electric vehicles and plug-in hybrid electric vehicles last year, with 2,68 percent.

Autonomous driving has a lot of advantages. Increased personal safety, mobility for non-drivers, time savings for drivers, less environmental impact, and lower transportation costs are just a few of these benefits. In the future, safety will always come first, while another focus will be on passenger comfort. Parking will not be an issue anymore as driverless vehicles will be able to drop people at their destination and come back for them later (Marr, 2022).

Shared mobility is an important complement to the traditional public transport system. Self-service bicycles, scooters, car sharing, and other modes of transportation are all rapidly expanding, because their characteristics make them cost-effective, convenient, and less stressful alternatives to car ownership. In Europe, in regards to the density of shared mobility, the Brussels-Capital region comes second after Paris (Serruys, 2021).

One thing is certain: mobility is changing. There is enormous momentum in this sector. The current system's unsustainable nature, the rate of technological development, urban populations' readiness to adapt to new ideas, and governments' willingness to act are

all likely to propel cities toward a cleaner, safer, and better future (McKinsey & Company, 2017).

5.2 Recommendation for further research

Around the world, megacities are trying to balance the benefits and drawbacks of the new modes of transport. Many of the new mobility modes that were expected to solve fundamental issues like traffic congestion or air pollution and improve quality of life are instead creating problems for city planners. For example, China has made bike sharing available in various cities in order to make urban transportation systems more environmentally friendly. However, authorities in Beijing were obliged to restrict the usage of shared bicycles because of the discarded vehicles that clog up already busy city streets. Following pedestrian crashes and fatalities, some megacities, including Paris and Singapore, have banned the use of electric scooters on sidewalks.

But as long as most private enterprises are permitted to pursue their profit-driven agendas unchecked, urban transportation will continue to degrade. Almost every megacity requires a plan to bring order to the transportation chaos and that is why Municipal authorities will have to take some responsibility for this. The plan must ensure that public and private operators in the fragmented mobility ecosystem work together effectively. In the world's biggest cities rising car ownership, aging, inefficient transportation networks and rising population all contribute to increased congestion and lower productivity. According to the World Economic Forum, the number of cars on the road will increase dramatically in the coming decades, rising from 1.1 billion in 2019 to 2.0 billion by 2040.

On-demand, shared mobility solutions were supposed to be the answer to urban transportation problems. However, in the absence of government intervention, many firms compete for market share. This situation has resulted in enormous private-sector investment and increased customer choice, but it has not resulted in improved transportation networks. Instead, due to an overabundance of modes, urban mobility has deteriorated.

Cleaner transport, automation, new business, models and new modes of travel promise to transform how people, goods and services move. However, if technological

advancements are not successfully managed, they may have unintended consequences, such as increased traffic congestion or reduced sustainable travel.

If only Municipal authorities reinvent themselves and coordinate public and private players, they will be able to create more integrated transport networks. That is why cities should prioritize solutions that deliver greater productivity, independence, and sustainability for consumers (Lang, et al., 2020).

The current study analyzes sustanaibility and innovative mobility in eight megacities, namely, Tokyo, London, Sao Paulo, Cairo, New Delhi, Shangai, Chongqing and Istanbul. Although the city mobility index developed by Deloitte let us have a clear view on various aspects including policies and practices, sustainable mobility is a much more broad concept. There are a number of gaps in our knowledge around the current topic in research that follow from our findings, and would benefit from further research, including: in-depth exploration of how mobility may affect green transition in megacities and how megacities have to reform their policies so as to guarantee the maximization of benefits.

Appendix

I. Performance and Resilience

Due to their inherent characteristics, megacities should ensure the existence of efficient and reliable mobility systems. Yet, this is quite a complex task. To assess performance and resilience we have to take into account a wide range of different aspects of mobility such as congestion, public transport reliability, transport safety, integrated mobility and modal diversity.

In terms of *congestion*, all the four cities (Istanbul, London, Sao Paulo and Tokyo) seem to be at the same level, yet a low one. Congestion seems to be a major problem for megacities.

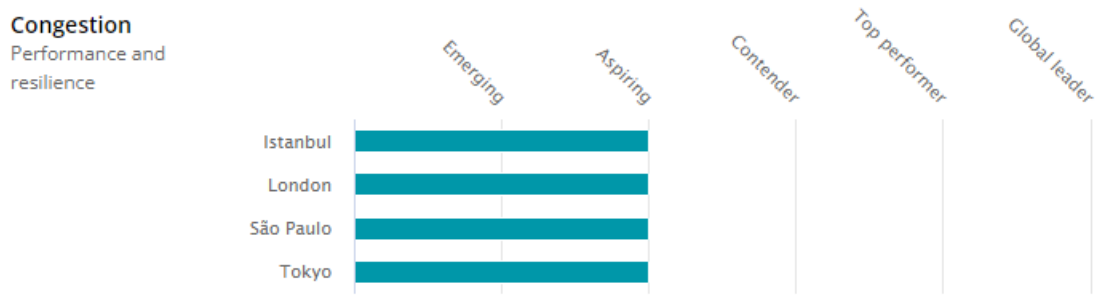

Figure 7: Comparative analysis – Congestion (Deloitte, City Mobility Index)

Much better results are achieved in public *transport reliability*, where Tokyo is definitely a leader compared to the other cities.

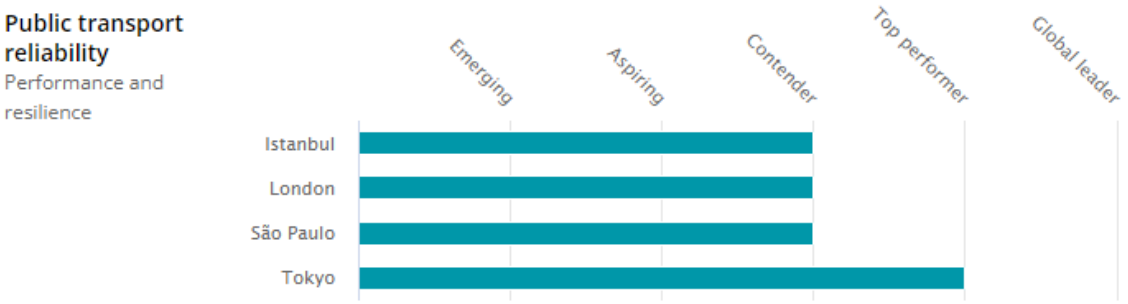

Figure 8: Comparative analysis – Public Transport Reliability (Deloitte, City Mobility Index)

Transport safety is surely a matter of utmost concern in modern cities. Tokyo again is a global leader in this field, while Istanbul and London significantly lag behind. Sao Paulo

has to pay extra attention in safety so as to guarantee a smooth transition to sustainable mobility.

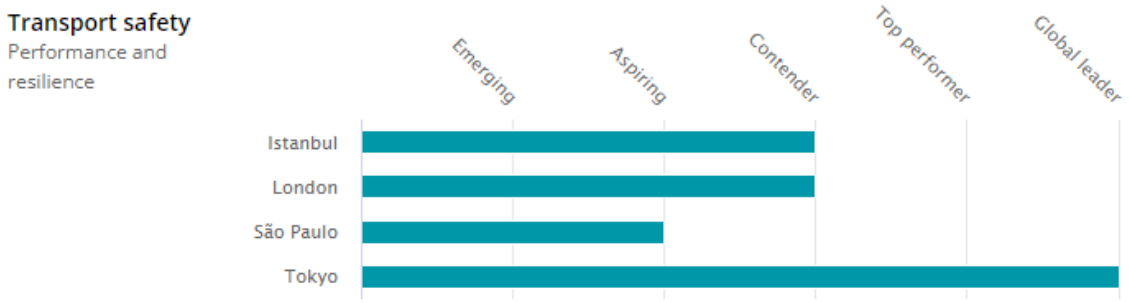

Figure 9: Comparative analysis – Transport Safety (Deloitte, City Mobility Index)

An *integrated mobility* is critical for key stakeholders to adopt since the various mobility trends—infrastructure, autonomous driving, connectivity, decentralization of energy systems, electrification and public transit—are interrelated and will affect both consumers and businesses (McKinsey, 2022)

In that case, London, Istanbul and Tokyo are equally top performers while Sao Paulo makes greater progress compared to previous charts.

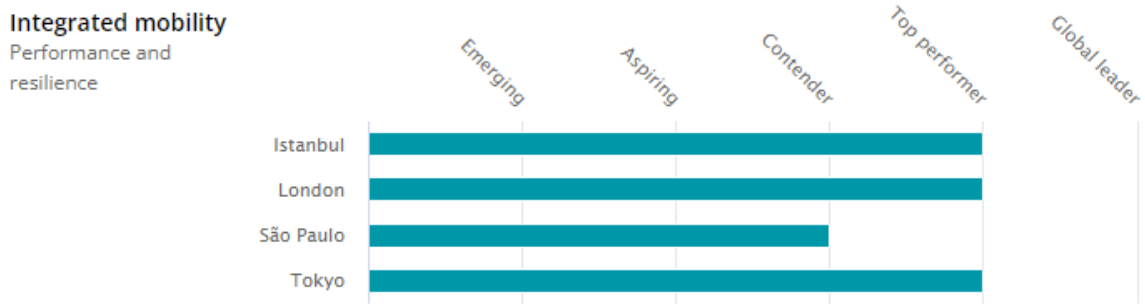

Figure 10: Comparative analysis – Integrated Mobility (Deloitte, City Mobility Index)

Given the growing demand for mobility, it appears that society seeks greater variety and responsiveness in mobility forms. For *modal diversity* to work best, a seamless transition between modes is needed.

Istanbul is the global leader in this category as provide plenty of transportation means, while Tokyo and Sao Paulo following with significant performance. London lag behind compared to others.

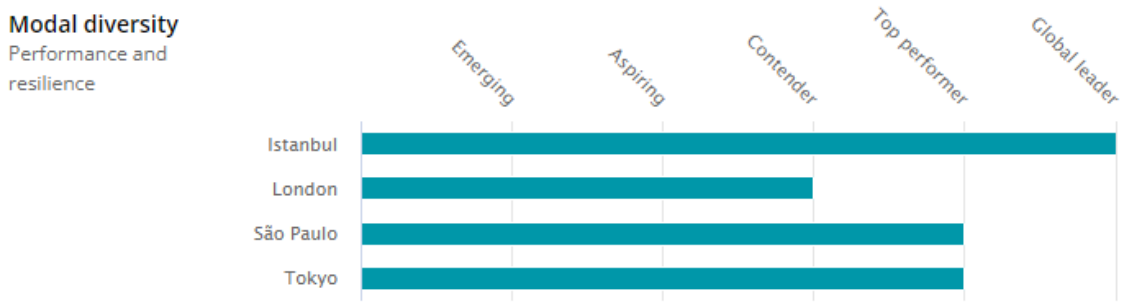

Figure 11: Comparative analysis – Modal diversity (Deloitte, City Mobility Index)

II. Vision and leadership

A high performing, resilient mobility system does not happen by accident. It requires planning: a clear direction, investment, coordination among stakeholders, and innovation. Environmental issues are also increasingly prominent, and the aim should be not just to minimize the negative impacts on mobility but also to promote positive outcomes (Dixon et al., 2020).

Cities should have a clear *vision and strategy* that transport fits into, such as clearly articulated plans for modal diversity, ticketing and payments, land use, environmental sustainability, technology/innovation adoption, inclusiveness and accessibility (Dixon et al., 2020).

London is a global leader in Vision and Strategy with Istanbul following this direction. Tokyo and Sao Paulo significantly lag behind compared to London.

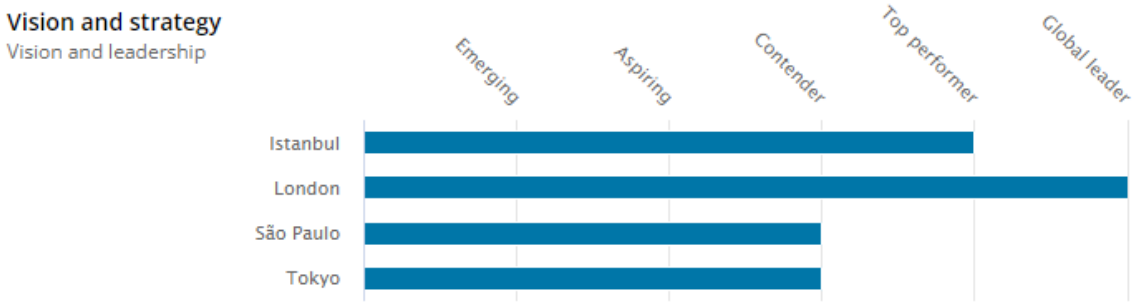

Figure 12: Comparative analysis – Vision and strategy (Deloitte, City Mobility Index)

A city's transport plan is only credible if there is sufficient *investment* to make it happen. The absolute amount is important, but so is the relative proportion of transport in the city's overall investment budget. Most cities obtain funding from different levels of government (central/federal, regional/state and local) and this can affect long-term planning (Dixon et al., 2020).

The leader in this case is once again London, while at the same time, Istanbul and Tokyo are at a satisfactory level.

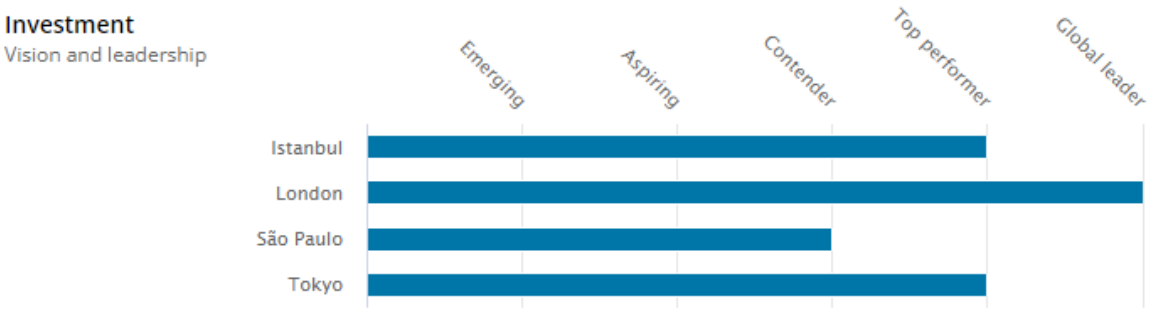

Figure 13: Comparative analysis – Investment (Deloitte, City Mobility Index)

Technology is changing the way in which transport is operated and accessed and cities are upgrading their systems with a range of digital capabilities. Real-time traffic management systems, intelligent traffic signals and smart equipment for payments and parking will be enabled through expanded connectivity and *innovation* (Dixon et al., 2020).

London is clearly a Leader in innovation in contrast with Sao Paulo which is dramatically left behind. Istanbul and Tokyo are again at the same-promising level in this category.

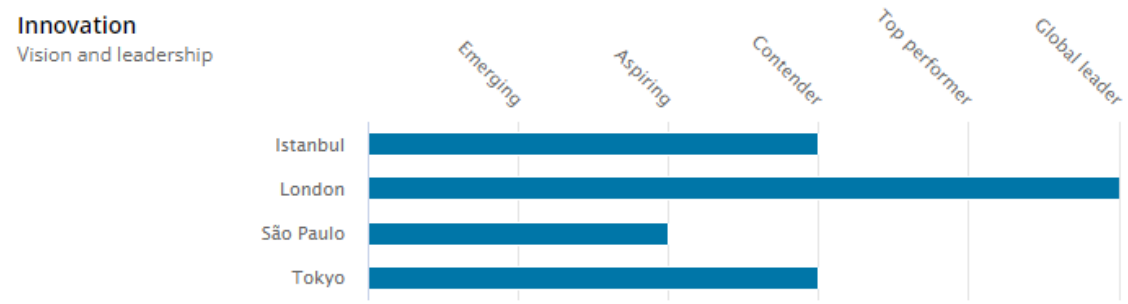

Figure 14: Comparative analysis – Innovation (Deloitte, City Mobility Index)

The *regulatory environmental framework* of a city affects transport innovation and the delivery of new products and services. That's why Regulations need to be open and flexible.

None of the cities are a leader in this case, but still London is beyond others. Surprisingly Sao Paulo is at the same level with Tokyo and Istanbul.

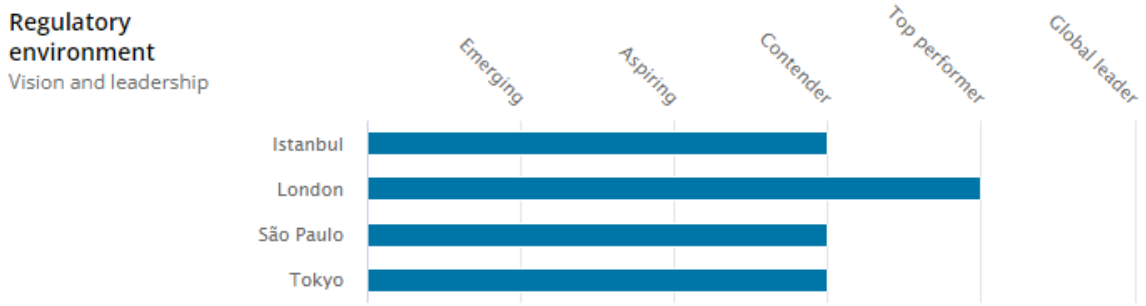

Figure 15: Comparative analysis – Regulatory environment (Deloitte, City Mobility Index)

The transportation sector is currently the largest source of greenhouse gas emissions, and authorities must address this issue immediately. In what extend are green transport means used, cycling or alternative-fuelled vehicles (AFVs), such as hydrogen fuel cells and compressed natural gas**.** *Environmental sustainability Initiatives* for reducing greenhouse gas emissions and provision of public and private infrastructure to support it, should be included (Dixon et al., 2020).

The data do not significantly differentiate from the previous chart, as long as London is the top performer in this category with Tokyo and Istanbul following. However, Sao Paulo does not record the same satisfactory level of sustainable initiatives like the others.

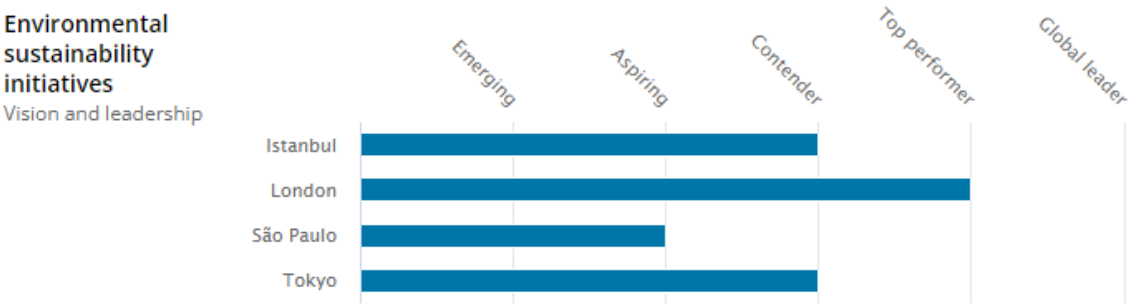

Figure 16: Comparative analysis – Environmental sustainability initiatives (Deloitte, City Mobility Index)

III. Service and Inclusion

Mobility in cities should be easily available to everyone, with wide public network coverage, affordable options, and user-friendly ways to access the various modes of transport.

This metric assesses the *public transport density*, the length of the rail network and bus rapid transit (BRT) routes, the number of railway stations and bus routes, by measuring all these as a ratio of the area's population and geographical size (Dixon et al., 2020).

London is far beyond the others with Tokyo following. Istanbul and Sao Paulo seem to lag dramatically behind the London.

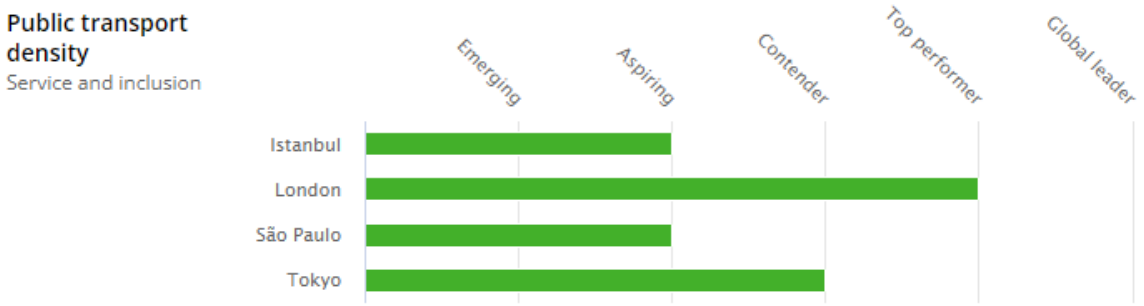

Figure 17: Comparative analysis – Public transport density (Deloitte, City Mobility Index)

The *transport affordability* refers to the average price of a monthly pass, a litre of fuel, taxi rides and parking, against an average monthly salary (net, after taxes) and a Cost of Living index, in order to measure the proportion of total incomes spent on transport.

London and Istanbul are at a low level in this category with Sao Paulo and Tokyo to be in a greater place. Not only that but Sao Paulo is surprisingly far ahead from London and Istanbul.

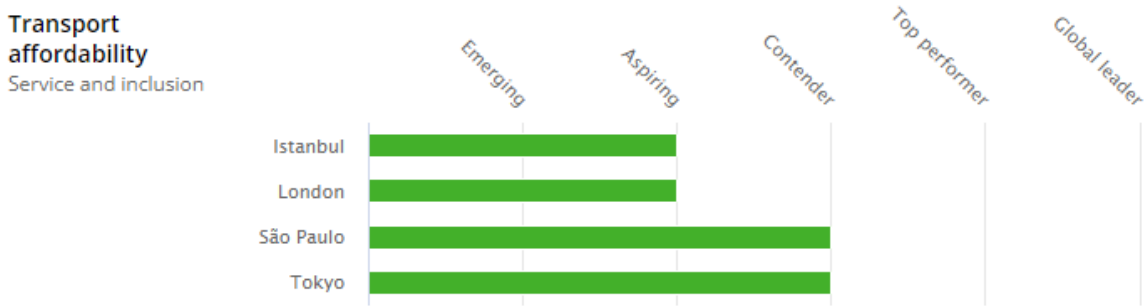

Figure 18: Comparative analysis – Transport affordability (Deloitte, City Mobility Index)

Policies to reduce air pollution have led to improved *air quality* over the last three decades. However, in some cities air pollution still poses risks to health.

Data for this category are disappointing as long as 3 out of 4 cities has low level of air quality, with London to be slightly ahead but not satisfactorily.

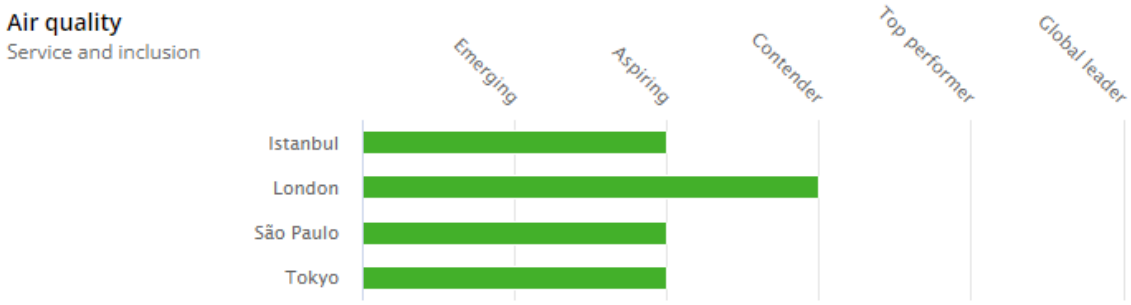

Figure 19: Comparative analysis – Air quality (Deloitte, City Mobility Index)

Increasing public transport use is recognized by many countries as crucial to the pursuit of a global strategy for environmental sustainability and improving urban mobility. So, understanding the *customers satisfaction* about the public transport service is essential to carry out this strategy.

Tokyo is top performer in this field with London following this direction. Istanbul is still at a low level while Sao Paulo is dramatically left behind compared to other cities.

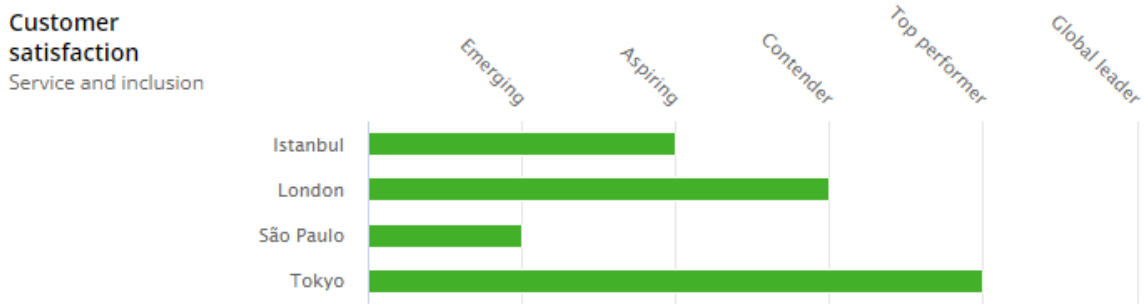

Figure 20: Comparative analysis – Customer satisfaction (Deloitte, City Mobility Index)

Last but not least, improving *accessibility* to urban transport plays a key role in achieving economic competitiveness, social cohesion and sustainable growth. Providing adequate travel conditions allows inhabitants to access and integrate into cities. This doesn't just

mean providing transport from home to work: it also means providing access to culture and leisure (Souza, 2019).

Sao Paulo seems to have a long way to go in this field while at the same time London, Tokyo and Istanbul are at significant level.

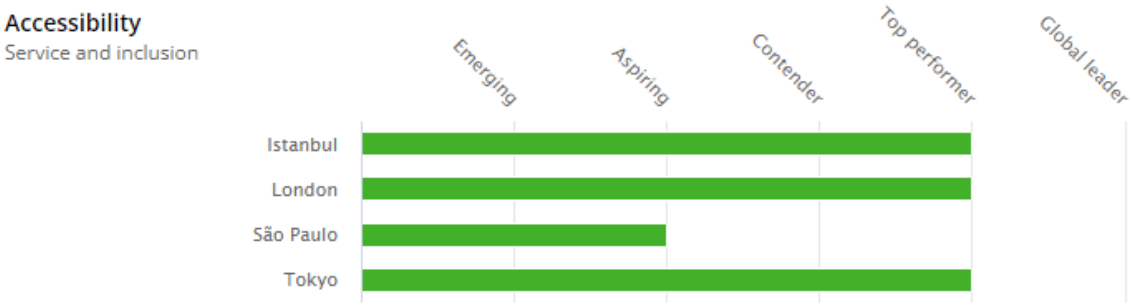

Figure 21: Comparative analysis – Accessibility (Deloitte, City Mobility Index)

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