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Sustainable Mobility Governance in Smart Cities for Urban Policy Development-A Scoping Review and Conceptual Model

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Abstract

Purpose

The aim of this study is to propose a governance model and key performance indicators on how policy makers can contribute to a more accessible, inclusive, and sustainable mobility within and across smart cities to examine sustainable urban mobility grounded on the rational management of public transportation infrastructure.

Design/methodology/approach

This study employed desk research methodology grounded on secondary data from existing documents and previous research to develop a sustainable mobility governance model that explores key factors that influence future urban policy development. The collected secondary data was descriptively analyzed to provide initiatives and elements needed to achieve sustainable mobility services in smart cities.

Findings

Findings from this study provide evidence on how cities can benefit from the application of data from different sources to provide value-added services to promote integrated and sustainable mobility. Additionally, findings from this study discuss the role of smart mobility for sustainable services and the application for data driven initiatives towards sustainable smart cities to enhance mobility interconnectivity, accessibility, and multimodality. Findings from this study identifies technical and non-technical factors that impact the sustainable mobility transition.

Originality/value

This article explores how urban transportation can greatly reduce greenhouse gas emissions and provides implications for cities to improve accessibility and sustainability of public transportation, while simultaneously promoting the adoption of more environmentally friendly means of mobility within and across cities. Besides, this study provides a detailed discussion focusing on the potential opportunities and challenges faced in urban environment in achieving a sustainable mobility. The governance model developed in this study can also be utilized by technology startups and transportation companies to assess the factors that they need to put in place or improve for provision of sustainable mobility services.

Social implications

This study provides implications towards behavioral change of individuals to adopt more sustainable mode of travels, increase citizens quality of life, improve economic viability of business involved in providing mobility related services, and support decision making for municipalities and policy makers during urban planning and design by incorporating the sustainability dimension into their present and future developments.

Practical implication

Practically this study advocates for the use of smart mobility and data driven services in smart cities to improve commuters' behavior aimed for long-term behavior change towards sustainable mobility by creating awareness on the society and supporting policymakers for informed decisions.

Implications from this study provide information that supports policymakers and municipalities to implement data driven mobility services.

Keywords: Sustainable mobility governance; Smart mobility; Connected mobility; Transport development; Smart cities; Built environment.

1. Introduction

Although, the transportation sector plays a crucial role in providing new areas for societal growth and have proven to be a catalyst for economic growth which positively influence the sustainable development of cities (Hansain *et al.,* 2020). The transportation sector contributes to the release of air pollutants, increase of energy consumption, and emission of greenhouse gases (Anthony Jnr, 2021b). Urban mobility is one of the most vital elements for the transportation sector within any city. Typically, urban mobility refers to the possibility of individuals to move within and across an urban space in a coherent and organized manner in accordance with their socio-economic needs, using available transport, services, and infrastructure (Šemanjski *et al.,* 2018). But the high number of population in urban areas (Tomanek, 2017), and global urbanization trends has resulted to increased need for efficient city services, sustainable transport systems, and air/noise pollution reduction (Anastasi *et al.,* 2013; Anthony Jnr, 2022) due to problems such as traffic congestion (Tripathy *et al*., 2020; de Carvalho *et al*., 2021). Moreover, managing public transportation needs to promote increased intermodal and multimodal mobility has become more complex and challenging task for municipalities. To tackle these environmental challenges from transportation, municipalities are leveraging digital technologies to unlock new potentials to dramatically change the future landscape and operationalization of transportation (Hansain *et al.,* 2020).

As digitalization transcends across the society (Anthony Jnr, 2021a), cities are looking for methods that ensure a sustainable, comfortable, efficiently viable future for their residents by becoming "Smart" (Betis *et al.,* 2018; Kormann-Hainzl *et al*., 2021; David *et al*., 2022; Ferrero *et al.*, 2022). Accordingly, cities are being technologically empowered as the infrastructures and systems are becoming integrated and interconnected, to break up silos enabling smartification of cities (IBM, 2009). The smartification of cities entails using digital technologies and data to strategically provide more effective, new or improved value-added services to residents (Nicolaï and Boennec, 2018; Alvsvåg *et al*., 2022). It also involves monitoring and tracking municipality administration's progress toward green policies including addressing climate change mitigation and adaptation targets. More importantly this includes the optimization and improving of existing city`s infrastructure, and plan to lessen silos systems in the city to enable more innovative business models for private and public sector sectors in the society (Nicolaï and Boennec, 2018). It further comprises of interconnected systems of services deployed through digital technologies aimed to improve the quality of life of citizens (Makarova *et al.,* 2017; Sanchez-Iborra *et al*., 2017).

The strategies for smartification of cities focused to enhance the existing services provided in cities making existing infrastructures more sustainable (Cassandras, 2017; Tomanek, 2017).

Accordingly, there is need for enhancing the synergy of transport and land use to foster an integrated, accessible, inclusive, and sustainable mobility services, while promoting the wellbeing, welfare, and quality of life for all. A novel paradigm towards urban mobility policy is required towards adapting to technological requirements and social and business changes (Anthony Jr, 2023). Moreover, there are fewer studies that examined governance measures to be employed towards sustainable mobility practices to implement more effective, safe, secure, and efficient mobility experience for individuals by reducing cost, time, and delays (Hansain *et al.*, 2020; Ribeiro *et al.*, 2021). Thus, this article aims to investigate the following research questions.

- What are the initiatives and elements needed to achieve sustainable mobility in smart cities?
- How can the use of data from different sources support sustainable smart mobility governance?
- Which factors and key performance indicators (KPIs) may influence sustainable mobility governance for future urban policy development?

To address the above research questions, this study aims to propose a governance model and key performance indicators on how policy makers can contribute to a more accessible, inclusive, and sustainable mobility within and across smart cities to examine sustainable urban mobility grounded on the rational management of public transportation infrastructure. The proposed governance model is developed based on key factors that influence future urban policy development. This study contributes to knowledge by proposing a governance model that promote sustainable mobility solutions by reducing the utilization of infrastructural and environmental resources. Also, this study further examines how data can contribute to provide an integrated, accessible, inclusive, and sustainable mobility solutions for the society. The remainder of this article is structured as follows. After this introduction section, the next section provides a literature review of previous studies on the study area. Section 3 outlines the methodology employed to perform this research, where a systematic literature review was applied to explore sustainable mobility development. The findings of this study are presented next in Section 4, followed by the discussion and implications of the study for transport policy and practice in Section 5. Then, Section 6 presents the conclusion, the limitations, and future directions.

2. Literature Review

Nowadays urban mobility is undergoing a great change as such sustainable modes of transportation are a key concern for municipalities and smart cities across the world (Behrendt, 2019). Also, urban inhabitants are becoming more aware about their carbon footprint and are now employing more greener mobility options (Sanchez-Iborra *et al*., 2020), as such some works have contributed towards this goal. Among these studies Acheampong *et al.* (2021) examined if autonomous vehicles can support sustainable mobility within future cities. Findings from the study provided discussion around policy challenges from the user’s viewpoint on different urban transport options.

Further findings from the study explored on how socio-demographic and behavioral variables can influence the adoption and use of autonomous vehicles based on survey data. Based on this, the authors studied how autonomous vehicles could change travel behaviors via sustainable mode choice. Kırdar and Ardıç (2020) presented a design scheme for unified smart mobility application to change the behavior of commuters towards minimizing car dependency and adopting sustainable mobility with the use of smart mobility systems. The focus of the study is to promote travel behavior change by employing technology via a sustainability aware travel service.

Another study by Soe (2020) examined mobility practice within smart cities and discussed the role of automated vehicles in urban transportation. The author discussed whether urban transport in future cities will be completely or incrementally autonomous and also determined the barriers and enablers of entirely autonomous urban transport procedure. Moreover, a roadmap is provided for policymakers regarding the implementation of autonomous vehicles. Croce *et al.* (2019) explored energy resources and sustainable mobility by carrying out a quantitative assessment of the transport services combined with electrical vehicles. The objective of the research aimed to propose a framework that facilitate decision-making and optimization of transportation services for individuals in an effort to decrease renewable energy resources. The research developed a framework implemented to design transportation services driven with Electric Vehicles (EVs), while guaranteeing mobility requirements to support green transport services for individuals.

Furthermore, Hipogrosso and Nesmachnow (2019) explored sustainable mobility concepts in public transportation. The study presented possible sustainable mobility strategies developed based on a case study of well-known qualitative and quantitative indicators. Three mobility modes were studied (electric bus, electric scooters, and public bicycles), and specific suggestions were framed to extend and enhance sustainable mobility. Papageorgiou and Demetriou (2019) examined diffusion and learning initiatives for sustainable urban mobility development. A model was designed that provides key strategies and possible effects towards changing the mindset of individuals to be more physically active in their mobility around a city. Based on a case study the authors contextualized and demonstrated existing active mobility issue towards developing scenarios for encouraging a walking mindset. Mozos-Blanco *et al.* (2018) provided a comparative analysis of sustainable mobility plan to address the identification and evaluation of diverse mobility measures, definition, costs, and the implementation procedures, etc. The study also provided measures, indicators, and guidelines for sustainable mobility plan. Aletà *et al.* (2017) explored smart environment and smart mobility in cities. The study focused to dynamically depict smart city development initiatives from the lens of mobility and environmental problems as two of the major areas of smart city development.

Bakogiannis *et al.* (2017) utilized conventional and digital technologies to foster sustainable mobility targets towards smart city transformation. Evidence from the study focused at presenting a collection of measures aimed at promoting sustainable mobility measures, infrastructures, and policies in order to contribute to the smart city domain. Benevolo *et al.* (2016) studied smart mobility within smart city context. The study aimed to investigate smart mobility initiatives, and also the role of Information Communication Technologies (ICT) in promoting smart mobility measures, as well as their impact on the citizens' quality of life. Semanjski *et al.* (2016) employed big data for sustainable mobility policy towards a planning support system. The study described a policy concept and included user created content into the policy system for sustainable mobility planning based on a real-life instance to establish the pertinence of big data method within smart cities planning procedures. As reported in the literature (Anthony Jnr *et al.*, 2020; Tripathy *et al.,* 2020; Bokolo *et al.,* 2022), municipalities have been faced with issues in achieving sustainable mobility such as the inadequate interoperable systems that enables interaction between public transportation, unawareness, and lack of citizen engagement in sustainable mobility initiatives and most importantly mobility exclusion. Although prior studies have largely explored the mechanisms to be employed to help cities achieve sustainable mobility solutions.

The sustainable mobility initiatives in smart cities, elements for sustainable mobility services in smart cities, and main factors that influence sustainable in public transportation service has not been well addressed. Additionally, while prior studies mainly address the technological and organizational issues to improve the sustainable mobility travel patterns. There seems to be little consensus about the governance measures needed for sustainable mobility policy development in smart cities. Secondly, the governance of sustainable mobility is often focused to enhance resource efficiency and less concerned with changing travel behavior and modal split. Moreover, mobility needs are fairly different across different parts of the city and in different locations, requiring diverse strategies (Berger *et al*., 2014). Hence, there is need for a governance model that promotes and effectively boost user acceptance of technological innovation in urban environment. This has been very challenging as it involves a combination of advanced digital technologies, organizational strategies, regulatory structures, societal involvement, and availability of a common and pluggable platform to integrate data from different sources to support sustainable public transportation.

3. Methodology

3.1. Research Method

A Systematic Literature Review (SLR) method is employed in this research to guide the review process. SLR process entails identifying and assessing the current literature on a specify domain such as sustainable urban mobility (Anthony Jnr, 2022; Anthony Jr, 2023). Therefore, SLR was carried out to examine sustainable mobility trends and solutions for future urban policy development. The SLR method starts with a review protocol that helps to identify research questions, objectives, and methods to carry out the review. The SLR method depend on a clearly detailed search strategy to structure the literature to identify the knowledge gaps. Figure 1 shows the SLR processes employed in this study.

3.2. Research Protocol and Search Strategy

The literature search was conducted in July 2022 and later in May 2023 using keywords from the selected scientific databases which comprises of google scholar, Scopus, and Web of science. The keywords used for the search included *"sustainable mobility" or "green mobility" or "environmentally friendly mobility" or "sustainable urban mobility" or "green urban mobility" and "public transportation*"and "sustainable urban transport *", and "road transportation" or "smart cities" and "smart*" and "sustainable transport*" and "factors*" or "Data" and "digital technologies*" and "model*" or "framework" and " approaches*".* The search included journal articles, conference proceeding, book chapters and technical reports published in website such as in European Commission, and articles written in English. Also, only sources published from 2000 till date (2023) were considered in this study. The sources selected also provide relevant data to address the research questions presented in the introduction section of this paper.

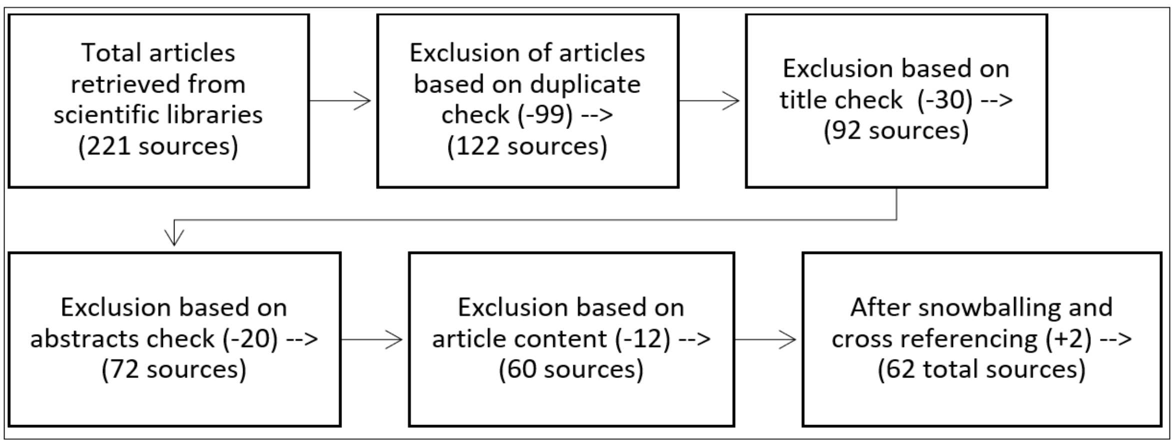

Figure 1 Sources selection process for this study

As seen Figure 1, a total of 221 sources were retrieved from the aforementioned scientific databases. After which a duplicate check was carried out and 99 sources were deleted as most of the articles retrieved from Scopus and Web of Science were also downloaded in Google Scholar. This resulted to 122 sources. Then 30 sources were removed based on the source titles not fully aligned to the study area which resulted to 92 sources. Next, 20 sources were removed due to the abstract not fully discussing sustainable mobility approaches. Furthermore, 12 sources were removed as the content of the sources was not well positioned to address issues related to sustainable mobility. Lastly 60 sources were aligned to the studied research area and further 2 sources were added via snowballing and cross references to strengthen the literature resulting to a total of 62 sources. The 2 sources were added as the authors discussed on the issues related to sustainable smart mobility (Acheampong et al., 2021; de Queiroz et al., 2021). To improve the reliability of this study the final sources selected as seen in the reference section provides secondary data to explores the research questions, which includes identifying initiatives and elements needed to achieve sustainable mobility in smart cities, discuss how the use of data from different sources can support sustainable smart mobility governance, and lastly specify factors and KPIs that may influence sustainable mobility governance for future urban policy development. The collected data was analyzed employing descriptive analysis. The data was extracted and synthesized into themes based on the research questions and study area being examined in the study.

4. Findings

This section provides more detailed discussion to the research questions presented in the introduction section of this study. Also, this section presents the sustainable mobility governance model in smart cities as an approach that comprises of key factors needed to foster future urban policy development.

4.1.Background of Sustainable Mobility in Smart Cities

The rapid increase in urban population and transportation needs of individuals global has led to a rapid demand for sustainable urban mobility policies and measures (Oke *et al.*, 2019; Anthony Jnr *et al.*, 2020). Findings from the literature suggested that the transportation sector has the biggest impact on municipalities pollution levels and energy consumption (Pinna *et al.*, 2017; Aifadopoulou *et al*., 2018). The transportation sector remains a key contributor for carbon dioxide emissions, amounting for almost 32.3 Metric tons of carbon dioxide equivalent (MtCO2-e) emitted from fuel combustion vehicles in 2016 (Oke *et al*., 2019), and it is projected that CO_2 emissions will increase up to 60 percent in 2050 if sustainable mobility measures are not employed. For these reasons, sustainable mobility is a significant concern for city`s transportation systems, and so for urban design and planning (Pinna *et al*., 2017). The need for sustainable mobility was initially defined in the 2001, within a Green Paper from the European Commission which was completed and issued in the mid-2007 termed as “green paper-towards a new culture for urban mobility” (European Commission, 2011).

According to the European Commission (2011), the proposal discussed in the report will significantly decrease Europe’s reliance on imported oil and decrease carbon emissions in the transportation sector by 60% by 2050. This extensive strategy (termed as Transport 2050) positions smart solutions and innovation at the core of future urban development and recognizes the significance of technology-supported mobility platforms towards the deployment of novel environmentally friendly transportation environment (Sanchez-Iborra *et al*., 2017). Sustainable mobility is an emerging domain that especially focuses on the policies and practices in transportation and environmental research to address issues such as road security, safety, air and noise pollution, traffic congestion etc. (European Commission, 2011). The term sustainable mobility safeguards that municipality`s transport systems meet the environmental, economic, and social needs whilst reducing their adverse impacts (Gallo and Marinelli, 2019). Sustainable mobility paradigm arose to strengthen the connection between land use and transport. The sustainable mobility examines the broad domain of transport that is green from the perspective of social, technological, environmental, economic, and climate impacts (Anthony Jnr, 2020).

Sustainable mobility aims at improving the accessibility while instantaneously minimizing social and environmental impacts to promote modal shift to decrease trip lengths and to achieve greater efficiency in the entire public transportation system (Papa and Lauwers, 2015). The shift from traditional mobility to sustainable mobility involves enabling the movement across and within cities with minimum environmental and regional impact while satisfying commuters travel needs (Kırdar and Ardıç, 2020). The sustainable mobility methods call for actions to decrease the need to travel (fewer trips), to promote modal shift, to lower trip lengths and to foster greater efficacy in the public transportation system (Mozos-Blanco *et al.,* 2018). In urban environment sustainable mobility provides a safe, secure, and interconnected public transport systems which includes cars, buses, trams, taxis, metros, trains, bicycles, and pedestrians foot paths (Battarra *et al.,* 2017). The use of one or more modes of mobility in different situations is termed as intermodal (using same mobility mode e.g., one bus and another connecting bus) and multimodal (using different mobility mode e.g., bus and train). Sustainable mobility prioritizes clean and often non-motorized options using real-time data to be accessed by the general public in order to save time, cost, reduce CO_2 emissions, and enhance commuting efficiency, improve network transport managers to optimize services and provide feedback to residents (Battarra *et al.,* 2017; Anthony Jnr, 2020).

Furthermore, municipality administrations are working on policies towards transportation planning to ensure that mobility is effective, and that users can utilize available multimodal and intermodal modes of transport in a quick, safe, and secure manner (Berger *et al.,* 2014; de Carvalho *et al.,* 2021). By deploying simpler cost-effective solutions that can absolutely change traffic congestions, decrease energy consumption, parking availability, and related economic losses (Venezia and Vergura, 2015), and improve urban mobility experience for citizens (Bokolo *et al*., 2022). Besides, these policies are concerned with promoting the use of multimodal and intermodal mobilities such as the walking, bicycle, shared mobility services which promotes the reduction of traffic congestion in smart cities (de Carvalho *et al.,* 2021). Findings from Figure 2 depicts possible sustainable mobility initiatives as suggested in the literature (Böhm *et al.,* 2013; Anthony Jnr *et al.*, 2020).

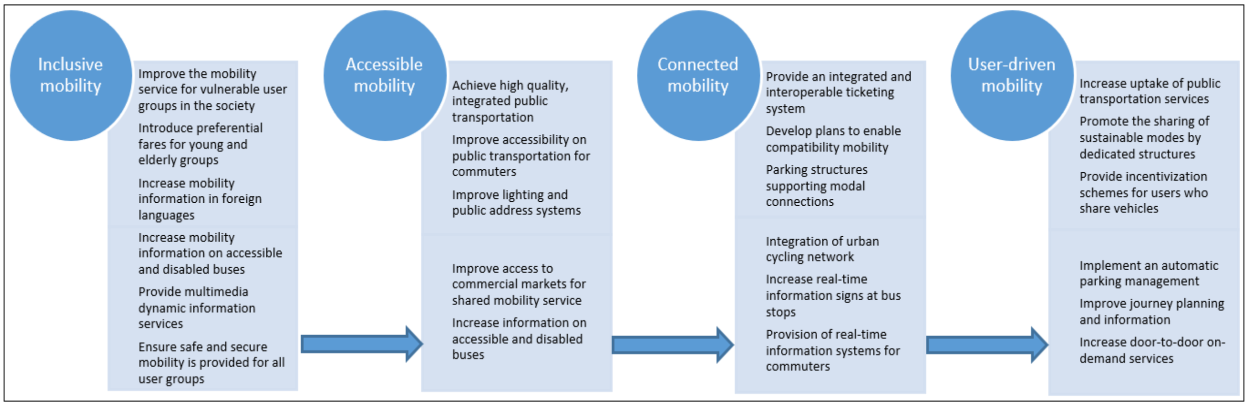

Figure 2 Sustainable mobility initiatives in smart cities

Figure 2 depicts possible sustainable mobility initiatives which is clustered as inclusive mobility, accessible mobility, connected mobility, and user-driven mobility.

4.2.Significance of Urban Mobility in Transport Policies

Modern urbanization has resulted to continuous growth and development of urban areas, which has resulted to generates increased demands for mobility services (Pinna *et al.*, 2017). As such research and development in urban mobility is important for future urban development as the actualization of an efficient public transportation system can address traffic congestion problems, as well as other issues faced in the transportation sector (Moreno Alonso *et al*., 2016). As such discussion on topics related to urban mobility is a prominent aspect of todays and future smart city development (Anthony and Petersen, 2020). Likewise, urban mobility is a top requirement in recent debates regarding green transition towards more sustainable mode of transportation (Berger *et al.*, 2014). Urban mobility is a key component in any urban environment as such it is seen as a key contributor towards a city being sustainable. This is because the mobility of people, services, and goods within and across cities is necessary for the growth and development of the economy and the society (Moreno Alonso *et al*., 2016). Urban mobility comprises of the public infrastructures that invariably shapes the urban environment such as the roads, public spaces, transport systems, and architectural solutions (Makarova *et al*., 2017).

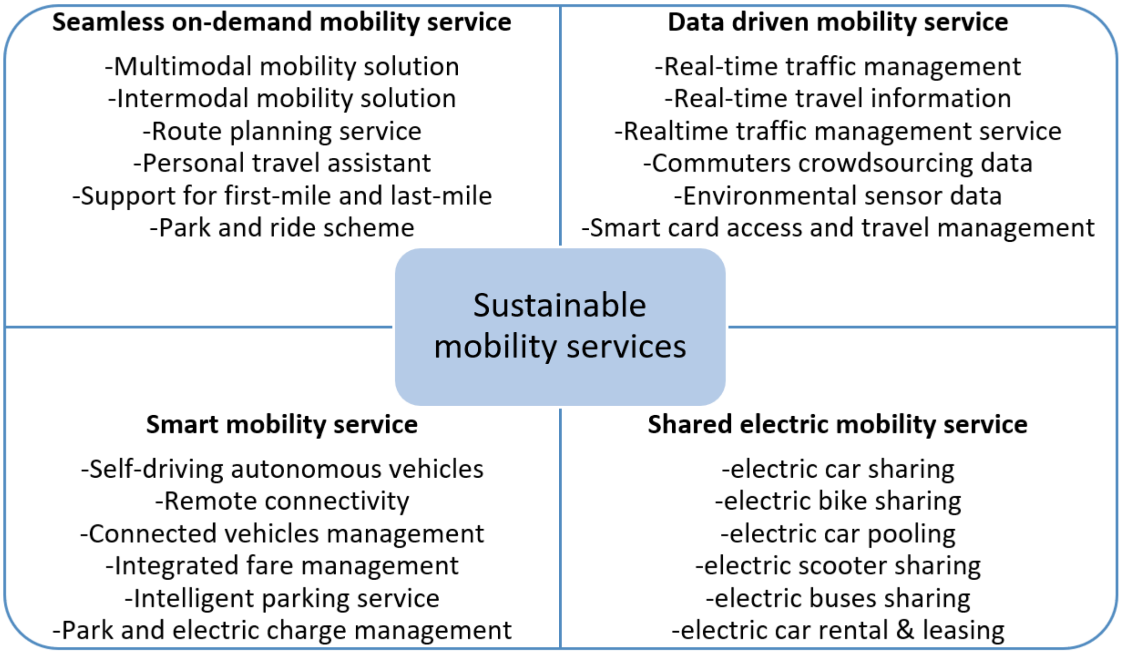

Figure 3 Typical elements for sustainable mobility services in smart cities

Figure 3 depicts the examples of elements needed to achieve sustainable mobility services in smart cities. These ranges from seamless on-demand mobility service, data driven mobility service, smart mobility service, and shared electric mobility service aimed to lower greenhouse gas, air pollution, and energy consumption. The elements aids towards addressing the concern associated to the creation of a smart, integrated, and sustainable mobility services that allows for deploying and monitoring seamless intermodal and multimodal travel modes integration. This helps to promote the usage of environmentally friendly, alternative energy source, thus creating innovative opportunities for shared collective mobility. For instance, high-capacity public transportation systems such as Bus Rapid Transit (BRT) metro, or light rail should be integrated and connected with other modes of public transportation such as shared electric mobility services to ensure full use of their capacity. Also, an example of the sustainable mobility initiative is the introduction of a "Park and Ride" scheme to lessen congestion in city centers to encourage reduced use of cars within the city and use of cycling instead of car use (Berger *et al.*, 2014). Overall, these integrated mobility service should also support first-mile and last-mile mobility services within and across cities to promote mobility accessibility in public transportation system (Makarova *et al.*, 2017).

As shown in Figure 3, in smart cities shared electric mobility services are being adopted in such as electric scooters which offers a new form of public transportation that has gained increased usage mostly in European cities as an alternative to driving within city centers. Electric scooters provide a green mobility substitute for short travels that are possibly too close to drive a car or too far to walk. Electric scooters service providers who manage a network of scooters offers an easy and practical way to use available electric scooters by merely downloading and installing the mobility application and entering a payment method. The electric scooters have in built Global Positioning System (GPS) for tracking that enables localization and usage of electric scooter (Hipogrosso and Nesmachnow, 2019). The use of electric scooters promotes door-to-door mobility, allowing residents and tourists to leave the electric scooters in designated locations within the operational area, thus offering a green intermodal mobility alternative in urban environment. Likewise, electric buses and electric cars also provides intermodal connectivity, limited to the availability of electric bicycles or electric scooters close to the bus stops (Hipogrosso and Nesmachnow, 2019). Finally, electric scooters are dock-less, easy to ride and find effortlessly, and can be parked in any location within the designated operational area. But, electric scooters are susceptible to road risks, as they are often using the same lane utilized by other automobiles, and are not a comfortable mean of mobility in some weather conditions e.g., raining, snowing, etc. (Hipogrosso and Nesmachnow, 2019).

To improve urban policy development there is need to rethink how to optimize flow of traffic, to encourage and increase the utilization of non-motorized transport or soft mobility such as cycling and pedestrian movement (Dev and Biswas, 2022; Sarker *et al*., 2020). Streets and public spaces need to be adapted, with road crossings, pedestrian walkways, and cycling lanes (Makarova *et al.,* 2017). Additionally, in most cities there are inadequate infrastructures for soft mobilities such as exclusive lanes that connects to bus stations across the city (Hipogrosso and Nesmachnow, 2019). Transport junctions need to be built to form connection points among different public transportation modes, thus promoting accessibility to and extending the range and usage of public transportation facilities, on both the macro level (the municipal, the region and global) and micro level (within the neighborhood) (Makarova *et al.,* 2017). In addition, to support soft mobility planning for bicycle infrastructure should consist of the bicycle lanes design, creation of bicycle parking areas, bicycle sheds and bicycle ways in relation to the road terrain and overall population of citizens who use bicycle to move around the city. Moreover, as shown in Figure 3 shared electric bicycles can be provided by the municipalities to help residents who use bicycle to move across areas with hilly terrains and rough terrains. Also, electric drives and bicycle-lifts creation can solve the problem to overcome steep climbs (Makarova *et al.,* 2017).

4.3.Smart Mobility for Sustainable Services in Smart Cities

A smart city is an urban area which deploys digital technologies, innovative business models, and solutions to enhance services provided to improve citizen welfare and the quality of services (Brčić *et al.,* 2018). The smartness of a city is mostly assessed based on its livability and efficiency as well as the use of innovative digital technologies (Makarova *et al.,* 2017; Sanchez-Iborra *et al*., 2017). The smartification of cities improves urban development by using data and digital technologies to provide more effective services to citizens (Ferrero *et al.,* 2022), to optimize and monitor existing infrastructure, and increase collaboration among different actors (Nicolaï and Boennec, 2018). Over the years the increasing number of personal cars in smart cities has led to congested road traffic, road accidents, and limited public space for residents has forced local municipalities to adopt green and environmentally friendly solutions for urban mobility (Brčić *et al.*, 2018). As such one of the main components of smart cities termed smart mobility is being employed in local municipalities. Smart mobility as one of the significant pillars within smart cities involves applying various digital technologies to improve public transportation and traffic management, which has become one of the biggest challenges for local municipalities (Brčić *et al.,* 2018). Smart mobility approaches also lead to significant social benefits, traffic safety, and also environmental and economic aspects are key to ensuring sustainability in future smart cities (Pinna *et al.,* 2017).

Furthermore, smart mobility offers a general paradigm for smart cities which comprises of a set of projects, plans, and policies that aim at improving the quality of urban life employing ICT solutions and participatory governance. By smart mobility this study mean ICT supported and integrated transport, which is also interconnected, intermodal, multimodal, sustainable, safe, and secure. According to Niglio and Comitale (2015) smart mobility provides non-motorized clean mobility, supported by real-time data, more accessible to the society, in order to save costs, time, and optimize commuting effectiveness, and decrease CO_2 emissions. The smart mobility approach offers a medium to optimize existing urban infrastructure, services, and user behavior through the utilization and deployment of digital networks. Smart urban mobility systems leverage digital technologies to improve quality of life and inform decision-making (Niglio and Comitale, 2015). Above all, these systems are economically, environmentally, socially sustainable. In other terms, a smart mobility approach has to include not only the sustainability factors but also the quality-of-life planning of citizens within the applications in practice (Papa and Lauwers, 2015).

Smart urban mobility initiatives comprise of a series of measures to enable the mobility of individuals, either by bicycle, on foot, or on private or public transportation to reduce social, economic, and environmental impacts. The citizens should come first for all mobility solutions relating to urban development (Aletà *et al.,* 2017). Smart urban mobility should comprise of continuous mobility chains (individual, private, and public transport), which are not only user-friendly and cost-effective, but efficient as well. Smart urban mobility seeks to facilitate and exploits new methods such as seamless on-demand mobility service, data driven mobility smart mobility service, shared electric mobility service, self-driving vehicles, and mobility services (Aletà *et al*., 2017). Moreover, through smart mobility approaches relevant information can be provided to commuters, public transportation networks operators, and other stakeholders who might be interested to contribute to long-term urban policy planning. Findings from Niglio and Comitale (2015) estimated that smart mobility technologies can reduce traffic congestion by 15 percent and enhance energy efficiency by 20 percent. Thus, smart urban mobility is one of the main important elements for public transportation systems in future cities (Brčić *et al.,* 2018).

Smart urban mobility entails using available data for urban planning and management to improve information availability in order to change people's behavior (Jnr, 2020; Jnr *et al*., 2020), promote the efficient use of natural resources to reduce waste to preserve the natural environment (de Queiroz *et al.,* 2021). Smart urban mobility can be seen as a system capable of deploying available data in an intelligent and extensive way, in order to reduce cost, time, and delays faced in public transportation and, above all, citizens quality of life. Smart urban mobility should be viewed as a whole as a linked organic network system which represents the ultimate goal in which urban investments are safeguarded to achieve a sustainable growth, in environmental and economic terms intended at improving the society (Papa and Lauwers, 2015). This is achievable by optimizing the public transport services and increasing connectivity, resulting to a more sustainable transport in general, with decreased traffic volume and emission levels, being optimized to meet the demands and requirements of inter-modality. Smart public transport systems are highly flexible, providing consumers more versatility in transport modes, routes, schedules, service providers and payment systems. Furthermore, smart mobility contributes to the overall design of smart cities by transport network's efficiency, better management of parking spaces, and advancing public transport's usage rate and its supporting policies (Ribeiro *et al*., 2021).

4.4.Data Driven Initiatives towards Sustainable Smart Mobility

Public transportation is one of the most valuable facilities needed to support the functioning of any urban area. However, the transportation sector produces some negative impacts which affects citizens quality of life such as air pollution, noise pollution, traffic congestion, CO_2 emission, and so on (Benevolo *et al.,* 2016; Nourian *et al.,* 2018). In achieving sustainable smart mobility there is need to focus on the technological perspective as related to "data". This is due to the fact that data possess the capability to support urban mobility policies and offering sustainable intermodal and multimodal mobility via multifunctional data analysis and visualization for decision making support as a policy tool (Bokolo, 2023). To this end data driven initiatives is required to be employed to lessen pollution (Anthony Jnr, 2022), decrease traffic congestion; increase the safety of residents and visitors; reduces noise pollution; enhance intermodal and multimodal mode of travel thereby reducing transfer time and costs (Benevolo *et al.,* 2016). By smart mobility this study mean data driven, green, and integrated transport systems provided to individuals. To achieve a sustainable smart mobility in local municipalities the integration between digital and physical is important (Papa and Lauwers, 2015).

However, in most cities' commuters use different mobility mode and the interchange between these mobility services are not sufficiently optimized to connect travelers which is important to reduce time and associated cost. There is need for smart trip planning based on real-time data, that promotes sharing and co-use of transportation resources, park and ride schemes, and promotion of soft mobility (walking and bicycling) (Böhm *et al*., 2013). Moreover, existing mobility services are not sufficiently interconnected and work in silos (Anthony Jnr *et al.,* 2021). This stress the need for data integration of available mobility services and real-time dynamic on-trip information support (Böhm *et al*., 2013). Therefore, the goal of employing data within the mobility environment is to achieve interoperability, integration, and alignment of digital, human, and physical systems within the built environment to achieve a sustainable and inclusive future for the society (Papa and Lauwers, 2015). Using data collected from different sources such as social media, traffic flow, weather, location of users, pollution levels, parking availability, delays of transport services, available public transportation, mobility related services will be processed and provided to keep the users informed with optimal routes in real-time (Anastasi *et al.*, 2013). This will consider the traffic situation, the accessibility, and the likely delays for any means of public transportation (both flexible and scheduled), the level of pollution, possible roads closed due to accidents or road works, traffic jam, etc. (Anastasi *et al.*, 2013).

The data produced can be used by the transportation department at the municipality to detect sections of the road that requires maintenance (Sanchez-Iborra *et al*., 2017). The data can also be used to provide values added mobility related services such as social behavior, real-time prediction of events, traffic monitoring, and feedbacks for improvement of the traffic situation (Anthony Jnr *et al*., 2021). Data from social media can be employed to foster trust among commuters especially in car sharing and pooling schemes (Anastasi *et al.*, 2013). Thus, there is need for citizen-centric smart mobility that could be employed to increase sustainable mobility sharing using GPS tracking system and on-board logging sensor device that logs the speed and position of the shared electric vehicle using real-time data collected over Controller Area Network (CAN) used as remote connectivity. Real-time data collected over CAN should be able to provide information on the mileage, instantaneous energy consumption, real-time condition of the vehicle, etc. (Papa and Lauwers, 2015). Data gathered from sensor devices, smartphones, communicative channels, smart meters, and other Internet of Things (IoT) devices via energy-efficient, short-range wireless technology (i.e., ZigBee, IEEE 802.15.4, etc.) (Anastasi *et al*., 2013).

The collected data mainly from physical devices such as smart sensors, metering devices, and other IoT devices is pre-processed and filtered to address incomplete or noisy data. The data pre-processing mostly employ *data cleaning* to remove *inconsistent data and further filters noise*. Next, data from different heterogeneous sources are *combined and integrated* (Anastasi *et al*., 2013). This helps to accomplish the next step which is *data selection* carried out by identifying and selecting applicable data. The last step involves *preparing and transforming the data* to provide value added services to accelerate sustainable mobility in smart cities such as smart solutions to improve the mobility of walkers, pedestrians, drivers, cyclists, and transit users (Sanchez-Iborra *et al.*, 2017). The collected data via open data sources, crowdsourcing, etc. can be used to provide smart mobility services for instance *real-time congestion control or traffic management, smart parking systems, transport fare management, route optimization and planning real-time commuter information, mobility sharing services, multi-modal and intermodal transportation management, etc.* (Sanchez-Iborra *et al*., 2017; Anthony Jnr *et al*., 2021).

"*User centred mobility services*" such as "personal travel assistant" can be provided using open data which supports pre-trip planning, information support for on-trip planning, and finally amidst the main journey execution. The personal travel assistant supports the trip planning in advance by recommending the best route alternatives for the entire journey chain either via intermodal or multimodal mode. This mobility service uses existing static or historical timetable data currently used by the public transportation systems and uses the estimated mean travel times. Although as pointed out by Böhm *et al.* (2013), there are fewer mobility systems that not only use historical and open data but also uses real-time or near real-time data (e.g., information on the location of the vehicles, possible delays, etc.), as well as open data on the current weather conditions, availability of other expected means of transportation and possible route optimization to guide commuters during their trip using real-time data (Böhm *et al.*, 2013). During the journey real time spatio-temporal data about the transportation fleet, available seats, current traffic information, estimates of travel time etc. are used to provide an enjoyable and pleasant travel experience for the commuter.

By providing timely information as update regarding the progress of the journey, guiding the commuter in the transitions in intermodal/multimodal trip, as well as in re-planning of the trip in case of an unexpected events in journey chain or change of commuter's plans, etc. (Böhm *et al.*, 2013). Additionally, mobility data from sources such as Waze, TomTom, openstreetmap, Google, Inrix, etc. provides "socially collected" or "crowd sourcing" traffic flow and traffic incident data collected from different users' input are used to improve travel and navigation related services for commuters. This data sources (open data), also provides information on different points of interest, walking and bicycle routes, keep track of available charging stations for EVs and for motorized vehicles diesel/fuel prices across gas stations etc. in digital platforms to improve individuals' observations to improve their navigation within and across cities (Kelpin *et al.*, 2007). Similarly, crowd sourcing data from users' observations (e.g., reporting of potholes in the public road), may significantly also accelerate and optimize road maintenance with respect to urban planning and development. Such crowd sourcing data could even become commodity that could be traded through peer-to-peer data marketplaces (Kelpin *et al.*, 2007; Böhm *et al.*, 2013; Anthony, 2023).

4.5. Developed Sustainable Mobility Governance Model in Smart Cities

Over the years several cities are now adopting sustainable transportation means such as electric motorcycles, electric scooters, electric bicycles, or electric car, due to their eco-friendly features to promote sustainable mobility and healthy lifestyles (Sanchez-Iborra *et al*., 2020). Although, the current sustainable transport planning aimed at improving urban mobility, especially transiting from motorized vehicles to green energy-based vehicles. *The conventional sustainable transport planning employed by cities has not adequately assessed the impacts of factors that may influence sustainable mobility governance for future urban policy development*. A sustainable mobility governance model is a strategic planning and design tool designed to help achieve the public transportation needs of communities and enterprises within cities and their surrounding environment towards a better quality of life. It is grounded on existing mobility planning practices and includes stakeholders' participation/engagement, data integration/alignment, data interoperability and assessment principles (Gallo and Marinelli, 2019). Thus, to achieve an inclusive, integrated, safe, and smart mobility, a set of key factors connecting people, policies, systems, organizational, and digital interconnected solutions must be identified, addressed, and analyzed. Therefore, sustainable mobility governance would require elements that involve an alignment where *technical and non-technical factors* influence the sustainable transition processes (Berger *et al.*, 2014; Anthony Jnr, 2021b), as shown in Figure 4. Each of the identified factors presented in Figure 4 influences sustainable mobility governance for future urban policy development and should be considered by municipalities.

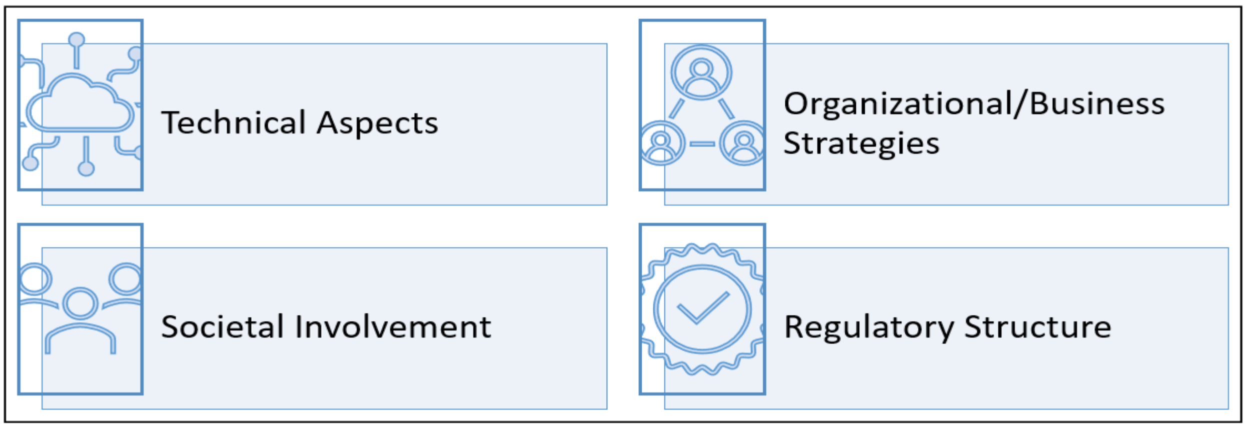

Figure 4 Developed sustainable mobility governance model in smart cities

Figure 4 depicts the developed sustainable mobility governance model in smart cities. The proposed sustainable mobility governance model promotes public transportation service to be seamlessly operated towards a digital, economic, social, and environmental system. By enhancing the utilization of digital technologies, collaboration of businesses and communities, and improving existing regulations and bureaucracy, sustainable mobility can be improved in smart cities. Each of the identified factors specified in the model are further discussed below.

4.5.1. Technical Aspects

The "*technical aspects*" which is related to the physical infrastructure is one of the factors that impact sustainable mobility governance as identified from the literature. It comprises of the public transportation system (such as the electric vehicles, charging infrastructure, toll management, parking facilities for cars, bicycles, etc.). In this regard, technological inventions have been acknowledged as one of the key tools that helps cities to improve energy efficiency, decrease air pollutants and reduce greenhouse gases (Hipogrosso and Nesmachnow, 2019; Anthony Jnr, 2021b). Accordingly, the technical aspect provides a sustainable mobility system that provide dynamic routes for public transportation based on the current demands of individuals at any time. These comprises of a different multimodal and intermodal mode such as electric car sharing, electric carpooling, on-demand bus service, rapid bus transit, train, metro, among others (Ribeiro *et al.*, 2021). The technological inventions offer a new mobility approach that integrates different transportation modes (mostly electric), and networks with the objective of optimizing existing mobility capacity, provide tailor-fit mobility needs for different citizens based on their social characteristics, considering their digital literacy level. Moreover, such mobility development should be inclusive to meet the diverse citizens' demands and should promote citizen engagement to adopt sustainable mobility solutions (Ribeiro *et al.*, 2021).

4.5.2. Societal Involvement

Achieving sustainable mobility requires social participation which can be established by employing shared mobility which is significant in smart cities for the co-creation of mobility services for residents (Kauf, 2019). Therefore, the "*societal involvement*" is another factor which intends to transform the current operational public transportation system to a more comprehensive, sustainable, and different user centred mobility service, employing a modern bottom-up approach as opposed to the traditional top to bottom to provide seamless electric mobility chain within and across cities (Ribeiro *et al*., 2021). It aims to promote an environmentally friendly efficient urban mobility and constantly prioritizing the transport needs of end-users towards achieving user-centric services where electric mobility services are provided to users through an individual digital platform (Anthony Jnr *et al.*, 2020).

With inclusive, digitally unified public transportation system, the society can be active contributors of regional development and can take advantage of digitalization, thus contributing to inclusive mobility for all (Rodrigues and Franco, 2023). This also provides a means to working with the residents to identify citizen's views, their mobility needs and concerns regarding social cohesion, sustainability, and improved quality of life (Ribeiro *et al*., 2021). Findings from the literature suggested sociodemographic characteristics such as gender, age, education, etc. should be considered when providing recommendations for policymakers to develop an inclusive digital public transportation system that is equitable and integrated (Ribeiro *et al.*, 2021). Also, the economic and social vulnerability needs to be considered as well as the digital competences of some user groups in the society (e.g., elderly, disabled, etc..), who intends to use digital platforms for their mobility needs (Ribeiro *et al*., 2021).

4.5.3. Organizational/Business Strategies

The "*organizational/business strategies*" strives to increase the uptake of public transportation and improves the operability and resilience of sustainable mobility chains by promoting walking, cycling, and other green mobility choice in place of personal vehicles. In addition, the business strategy involves operating innovative mobility solutions such as electric car polling and sharing, self-driving electric cars and employing EV fleets' as alternative power supply for Vehicle-to-Grid (V2G) solutions and smart charging schemes (Paalosmaa and Shafie-khah, 2021). The "*organizational/business strategies*" (such as the individual car ownership, electric buses, electric scooters, electric car, and electric bike sharing, and ticketing and booking schemes). The *organizational/business* factor supports multimodal and intermodal mobility services by enabling trip planning, flexible payments, easy transactions, dynamic trip management, and a customized and personalized service according to the mobility needs of the user at any time (Ribeiro *et al.*, 2021).

4.5.4. Regulatory Structure

There is need to provide recommendations for policymakers on how to develop practical mobility applications for designing an inclusive digitalize transport system for future urban development, which encompasses the views of all mobility players, in particular the public transport actors. Policies and legislations on communicative implementation and development strategies to be deployed should be specified in order to create public awareness about new and innovative mobility approaches, so as to promote the adoption of sustainable mobility measures (Ribeiro *et al.*, 2021). The "*regulatory structure*" drives the enterprise goals/mission and end-user habits, etc. Therefore, to achieve sustainable mobility towards decreasing travel needs using digital technologies there is need for governance initiatives to be adopted such as integrated ticketing and/or intermodal transport links that promotes modal shifts from use of personal car to public transportation, use of shared electric mobility, walking and cycling in central locations within the city (Berger *et al*., 2014).

This also considers the regional development level and current forms of governance administration adopted in the municipality to address societal expectations and needs that can foster innovative, efficient, and better public transportation systems for the urban and peri-urban areas (Ribeiro *et al*., 2021). Furthermore, the existing regulatory structures can aid in mitigating traffic congestion, and decrease the need for parking spaces, thus positively improving land use and urban attractiveness (Paalosmaa and Shafie-khah, 2021). A well-planned regulatory structure would thus trigger a new paradigm shift in urban mobility causing several changes ranging from improving mobility accessibility within and across cities, from mostly service regulation to mainly activity regulation for better safety, quality, capability. Such regulatory policies can contribute to change users' perception from being car owners to an entire mobility service that is centred on public transportation from subsidizing businesses to subsidizing inhabitants to a culture of improved mobility accessibility and better quality of life for all (Ribeiro *et al*., 2021).

Accordingly, as local municipalities comprise of different cultural, historical, economic, political, demographic, and social context. This study investigates the legacy of "*business process requirements",* "*technological infrastructure implementation*", *regulatory structure*, and the "*societal involvement*" (including inhabitants, visitors, commuters to the city, and businesses) which are merely not users of the public transportation services but have an active and specific role in the sustainable mobility transition (Papa and Lauwers, 2015). These identified factors as shown in Figure 4 which influences smart city's goal towards achieving sustainable mobility service in smart cities for future urban policy development. Grounded on these identified factors,

Table 1 provides quantitative key performance indicators (KPIs) to be employed towards assessing sustainable mobility (Hipogrosso and Nesmachnow, 2019), as stated in the third research question

Table 1. KPIs for sustainable mobility adapted from (Hipogrosso and Nesmachnow, 2019)

Quantitative KPIs	Descriptions
Mobility coverage	The mobility coverage comprises of the expected areas where a particular mobility service is to be provided to the society. It also includes the user types of these mobility services such as public bicycles introduced mainly for city tourists. For example, electric scooters usage coverage is mostly limited to a particular zone or areas.
Mobility accessibility	This includes the number of the population served by a particular mobility service provided. The accessibility is determined based on the intersecting coverage environment with the entire population map in relation to calculating the total population in a particular zone.
Mobility affordability	The affordability involves the price associated to each mobility service provided. This KPI is computed for three popularly used public transportation modes (electric scooters, electric bicycles, and electric buses), by assessing short trips with a length of 15 minutes (which is the most common travel period for electric scooters use), and extended trips length of 45 minutes (the typical duration commuted in busses). A time-based fare is applied for electric scooters and electric bicycles, where in most cases the first charge of utilizing the public bicycles is set up till 30 minutes.
Mobility travel time	The mobility travel times comprises of the distances from one end to another end within a specified urban coverage area for each mobility service.
Total public finance	This includes the subsidies provided by the government to municipalities that uses green mobility services for public transportation. For example, cities that uses electric buses are granted subsidies to promote the replacement of 4 percent of diesel bus to electric. The running of shared bicycles service is entirely supported by the municipality to promote active and environmentally friendly mobility. However, the use of electric scooters does not get any financial support as they are mostly owned and managed by commercial or private companies.
Energy efficient mobility	Involves the use of clean renewable energy in public transportation modes. Electric bicycle is the most effective of these green initiatives, since it requires less energy sources. For electric scooters, less energy is required to charge the mobility assets. However, several other issues may arise, such as the use of non-renewable energy for charging electric scooters and distributing electric scooters, as well as the short life span of the batteries. Another is energy efficient mobility is electric buses which provide a green mobility over the diesel buses, as they generate zero emission.
Multimodal/ intermodal connectivity	The sustainable mobility initiatives operated within a designated area should provide full connectivity of shared bicycles with electric scooters and buses, as bus stations are typically located less than 100 m apart and electric scooters are accessible nearby. Overall, electric scooters accelerate door-to-door on-demand mobility, enabling citizens and visitors to park the electric scooters anywhere inside the operational area, thus providing a valid substitution for intermodal connectivity. Buses also promotes multimodal when a commuter travel from one bus to another bus going to a different route. Also, buses support intermodal connectivity, but this is limited to the availability of electric bicycles or electric scooters close to the bus stops.
Multimodal/ intermodal integration	Presently, there are fewer approaches that supports the intermodal/multimodal connectivity of different mobility modes such as electric scooters, electric bicycles, and electric buses as the current system lacks the provision of intermodal integration. This is caused due to the fact that each mobility mode focuses on their particular operation, without enabling integration with others. This has results to inadequate availability of information or route guidance needed by

	travelers, also the integration of a single payment method for all public transportation mode is required to provide efficient mobility.
Comfort and pleasure	The availability of up to data real time information of all available public transportation is identified as one of the required features needed by citizens. The availability of information can improve the trip comfort and pleasure for commuters.

5. Discussion and Implications of the Study

5.1.Discussion

Adopting digital technologies in urban mobility planning and management is termed smart city. A smart city considers the economic, prudent use of natural resources and improves the quality of life of citizens (Moreno Alonso *et al.*, 2016). Smart cities aim to achieve sustainable development in urban environments via the convergence and integration of digital and physical infrastructures with active participation of citizens. Therefore, one significant objective of smart cities is to provide a green built environment for residents, which includes transport infrastructures, buildings, and urban infrastructures that provides an efficient service, save money, and time. Smart cities increase competitiveness and productivity, decreases the environmental impacts of human activities, and provides better welfare for its residents. As the transportation system in municipalities is a constituent of smart cities, this study aims at investigating possible sustainable mobility initiatives categorized as inclusive mobility, accessible mobility, connected mobility, and user-driven mobility.

In addition, this research discuss elements for sustainable mobility services in smart cities and sustainable mobility governance in smart cities, which could be replicated across different cities around the world. Sustainable urban mobility is fundamental to the economy, environment, and wellbeing of the society. The availability of an integrated and available transport service is crucial to citizens quality of life as this can ensure inclusion, social cohesion, equality, and increase accessibility (Sanchez-Iborra *et al.*, 2017). Accordingly, findings from this study presents the role of smart mobility for sustainable services and the application for data driven initiatives towards sustainable smart cities to enhance mobility interconnectivity, accessibility, and multimodality. Soft mobilities such as cycling and walking will also have higher impact for cities being sustainable and should be considered in urban planning and design (Ribeiro *et al.*, 2021). Additionally, the integration and alignment between legacy and new transport infrastructures and digital technologies will create smart mobility infrastructures and value-added services to citizens, businesses, and municipalities (Anthony Jnr *et al*., 2020).

The use of real-time data, historical data, open data, etc. collected and analyzed will provide increased operational adeptness for mobility infrastructure, as well as for intermodality and multimodality. For example, the adoption of EV sharing and pooling schemes will reduce traffic congestion, air/noise pollution, free available public space in cities that can be utilized for other purposes, thus opening up additional possibilities for retrofitting current transport infrastructures. This article concerns assessing the impacts of factors that may influence sustainable mobility governance for future urban policy development by presenting a conceptual sustainable mobility governance model as a strategic planning and design tool designed to help achieve the public transportation needs of communities and enterprises within cities and their surrounding environment towards a better quality of life. Similar to findings from a recent study (Paalosmaa and Shafie-khah, 2021), the governance model proposed in this study helps to decrease pollution levels and carbon emissions from urban traffic and raise the adoption level of sustainable mobility solutions, based on the derived KPIs in Table 1, and also promotes city's investing in sustainable public transportation infrastructure.

The sustainable mobility governance model differs from the existing sustainable mobility approaches as it is grounded on existing mobility planning practices and includes stakeholders' participation/engagement, data integration/alignment, data interoperability, business strategies and regulatory structures. Furthermore, findings from this study provides recommendations to expand sustainable mobility initiatives for urban development by installing more bicycle stations, operating new routes/lines of the electric buses, providing pedestrian infrastructure to promotes walking and cycling, extending the routes offered or covering different routes, and expanding the operational areas made available for individuals to use electric scooters and electric bicycles towards to increasing accessibility (Hipogrosso and Nesmachnow, 2019). Concerning affordability, public transportation costs should be subsidized for low-income earners, elderly, students, young people, and other vulnerable groups in the society to promote mobility inclusion. Finally, to promote shared mobility coverage, more electric vehicles must be established and an articulated network of exclusive lanes for electric vehicles, as well as charging infrastructures will help to foster this development.

5.2. Implications for Transport Research and Management

Cities are currently the main place of residence for 54 per cent of the world's population (United Nations, 2014). Similarly, 64 per cent of all travel embarked on is in urban environments and the total number of travels in cities is projected to increase by 2050 (Mozos-Blanco *et al*., 2018). Thus, it is important for cities to improve mobility services and at the same time decrease traffic congestion, pollution, and energy consumption. This gives rise for sustainable mobility governance to provide a paradigm shift in public transportation to achieve less pollution, increase the economic viability, enhance social wellbeing, and promote more sustainable and smart cities of the future (Mozos-Blanco *et al*., 2018). Reducing private car-use, decreasing CO_2 emissions, lessening traffic congestion, addressing transportation induced stresses for public health and on the natural environment is significant in the shift toward a sustainable future urban. But presently, the public transportation ecosystem is increasingly becoming complex, especially in cities due to increase in mobility demand. This has also resulted to further mobility problems such as environmental pollution, noise, congestion, and traffic accidents, which negatively affects the quality of the public transportation and decrease mobility accessibility.

Moreover, this contributes to increased energy expenditure, travel delays, pollution when EVs are not used, and stress which reduces productivity and results to higher costs living for the society (Ribeiro *et al.,* 2021). However, it is evident that the contributions to the field of sustainable mobility in smart cities from the governance perspective are limited. But, to achieve sustainable mobility, governance measures are essential to control and manage the public transportation system in relation to technologies, individuals, and businesses. The governance process includes decisions regarding planning, designing, and deploying of the public transportation infrastructures and required services (*Croce et al.,* 2019). Findings from this study identifies *technical and non-technical factors* that influence the sustainable mobility transition. In addition, a novel sustainable mobility governance model that promotes public transportation service is proposed and a set of key factors concerning people, policies, systems, organizational, and infrastructures are identified. This study provides implications towards behavioral change of the individuals to adopt more sustainable mode of travels, increase citizens quality of life, improve economic viability of business involved in providing mobility related services, and support decision making for municipality and policy maker during urban planning and design by incorporating the sustainability dimension into their present and future developments. The governance model developed in this study can also be utilized by technology startups and transportation companies to assess the factors that they need to put in place or improve for provision of sustainable mobility services.

Additionally, findings from this study proposes the deployment of smart mobility services to help tackle the challenges raised by public transportation in urban environments under certain conditions. Smart mobility services can provide methods which enables full integration to better incorporate all public transportation modes. Indeed, smart mobility services can play a major role in securing future sustainable mobility to address existing environmental, economic, and societal issues. The provision of data from different sources can encourage more sustainable urban mobility behavior and at the same time promote efficient use of existing resources (infrastructure, energy, and vehicles) (Böhm *et al.,* 2013). The data collected from different sources such as the smart sensors, open data, historical data, etc. can be utilized for estimating some of the quantitative KPIs for sustainable mobility of the city as seen in Table 1, as well as other KPIs such as traffic congestion detection, the traffic flow, travel time via the main routes of the city, other associated socio-economic transport related characteristics, and environmental indicators (Aifadopoulou *et al*., 2018).

5.3. Implications for Transport Policy and Practice

The transportation sector is one of the main areas for economic growth and its role in the society is indispensable. An effective and efficient public transportation system not only promotes the economy with the mobility of people and goods, but its prominence is much greater, having a major impact on communities and the natural environment. The future of the urban mobility is presenting leaning towards the development of digital systems that are more focused on the citizens, ensuring inclusiveness, multimodal, intermodal, and accessibility while minimizing pollution and environmental impact, particularly, improving citizens quality of life (Ribeiro *et al*., 2021). In recent years, the use of data has gained importance for sustainable urban development. In the transportation sector, the use of data is enabling novel and emerging mobility solutions, according to the mobility needs of individuals, such as on-demand bus lines, carpooling, automated cars, and traditional public transportation (metro, buses, among others) (Ribeiro *et al*., 2021). Also, the data can be used to optimize shared micro mobility and shared-mobility schemes (e.g., electric car-sharing, electric scooter-sharing), and electric bike-sharing), with the prospect of reducing vehicle ownership and lessening negative impacts on the environmental and public health (Acheampong *et al*., 2019; Anthony Jnr *et al*., 2020). Prior studies have not investigated urban mobility policies required for cities to adapt towards technological requirements and social and business changes (Anthony Jr, 2023). Also, there are fewer studies that examined governance measures to be employed towards sustainable mobility practices to implement more effective, safe, secure, and efficient mobility experience for individuals by reducing cost, time, and delays (Hansain *et al.*, 2020; Ribeiro *et al.*, 2021).

Accordingly, findings from this study provides initiatives for the application for data driven initiatives towards sustainable smart mobility. The information derived from the data will be useful not only for citizens and the mobility providers who are administrators of the smart mobility platforms, but also for the local municipality to improve diversity in travelling options (Ribeiro *et al*., 2021). For instance, the analysis of GPS data will allow urban planners and designers to identify how individuals move within and across cities and, accordingly, this knowledge can be used to manage urban traffic flows. Additionally, using real time data stream municipality administrators can carry out real time visualization and assessment of anomalous traffic scenarios by comparing historical data of normal traffic flow with the real-time traffic data. The insight can be used for parking management, as the collected data can be utilized for real-time monitoring of available parking lots mangled by the municipality or business. Particularly, this data can be used to provide information to users on available parking lots (Anastasi *et al*., 2013).

As suggested in the literature (Hipogrosso and Nesmachnow, 2019), municipalities should install secure park and charge stations for shared EVs such as electric-scooters, electric-bicycles. A certain recommendation to improve sustainable mobility is to promote intermodal and multimodal connectivity between different public transportation modes that integrates different ticketing system that allows commuters to share different modes of travel using a single ticket to improve mobility affordability. In this regard, there is need for data driven services that provides real time data such as the availability of EVs, current EV location, displays of bus stops information, display of timetabling, etc. The available data can also be used to for improving access to information to users via mobile applications towards reducing waiting time, walking time, and the total travel times (Hipogrosso and Nesmachnow, 2019).

Practically this study advocates for the use of smart mobility and data driven services in smart cities to improve commuters' behavior aimed for long-term behavior change towards sustainable mobility by creating awareness on the society and supporting policymakers for informed decisions. Findings from this study provides information that supports policymakers and municipalities to implement data driven mobility services. Using available data from diverse sources policymakers can monitor the state of the existing transportation system and services. The analyzed data mainly assists in developing and improving urban mobility systems based on the identified KPI as seen in Table 1. Furthermore, this article, provides a detailed discussion focusing on the potential opportunities and challenges faced in urban environment in achieving a sustainable mobility. Possible sustainable mobility initiatives, elements for sustainable mobility services in smart cities, and current gaps related to application for data driven initiatives towards sustainable smart mobility are explored. The application of data in this study provides mobility related support for citizens which is central to maintain their behavioral change to choosing greener mode of travel which contributes to lessen air pollution, reduce noise pollution, and decrease CO_2 emission in cities.

6. Conclusion

It is predicted that almost 70 percent of world's inhabitants will reside in cities by 2050. This suggests a real necessity for sustainable modes of transportation in order to make urban environments better places to reside (Sanchez-Iborra *et al*., 2020; Ribeiro *et al.*, 2021). Sustainable mobility would necessitate reduction of the negative impacts from transportable (Berger *et al*., 2014). Smart cities involve the convergence and integration of physical and digital infrastructures with the participation of citizens and supporting policymakers and municipality administration in city governance. The actualization of an accessible, inclusive, and sustainable mobility facilitated by digitally interconnected public transportation service, requires an integrated approach that considers the mode of transport (motorized and non-motorized), territories (peri-urban areas and cities centers), people (active, young, and vulnerable road users), and digital technologies in order to achieve an equitable, cohesive, and sustainable smart cities (Ribeiro *et al.,* 2021).

In particular, there is need for an approach that orchestrate the digital technologies, infrastructures, business strategies employed by organizations that provides transport systems, including all mobility players and transport companies, together with citizen's expectations needs, and views, and the support of regulations and polices related to public transportation. Therefore, this current study provides governance measures and key performance indicators on how policy makers can contribute to a more accessible, inclusive, and sustainable mobility. A desk research methodology was employed grounded on secondary data from existing documents and previous research to conceptualize the sustainable mobility governance model that explore key factors that may influence future urban policy development. Descriptive analysis was carried out on the collected secondary data to provide evidence on the sustainable mobility initiatives, elements for sustainable mobility services, and application of data driven initiatives towards sustainable smart mobility in smart cities.

Finally, this article gives some insights on the discussion on the smart mobility for future urban development by providing a through set of governance measures that integrates infrastructures, digital technologies, citizen participation, urban policies and regulations, and business environments. Findings from this article would be useful for transportation companies, municipality administration, and operators of urban mobility services to promote an accessible, inclusive, and sustainable mode of commuting in smart cities. This study provides evidence from existing literature only as best practices focus on promoting sustainable mobility policy guidance including conventional and innovative approaches driven by data for improved mobility services. Future works will collect qualitative data from mobility service providers, citizens, and municipality administrators based on multi-case studies to further validate the governance model developed in this study. Although this article does not entirely address all mobility issues faced by municipalities, evidence from this study make an interesting contribution to the domain of sustainable public transportation.

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