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Data enabling digital ecosystem for sustainable shared electric mobility-as-a-service in smart cities-an innovative business model perspective

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ABSTRACT

Increase in urbanization drives the need for municipalities to make mobility more efficient, both to address climate goals as well as creating a smart living environment for citizens, with less noise congestion, and pollution. As vehicles are being electrified, further advances will be needed to meet social, environmental, and economic sustainability targets, and a more efficient use of vehicles and public transport is central in this endeavor. Accordingly, Electric Mobility as a Service (eMaaS) has developed as a concept with the potential to increase sustainability mobility in cities and been designated as a phenomenon with potential to radically change how people move in the future. But presently there is the lack of a common business model that supports complex integration of all actors, digital technologies, and infrastructures involved in the eMaaS business ecosystem. This study aims to support the further development of eMaaS by providing a state of the art of eMaaS and further proposes a digital ecosystem as a business model for eMaaS sharing in smart cities. Accordingly, a systematic literature review was adopted grounded on secondary data from the literature to offers a new approach to urban mobility and demonstrate the suitability of the eMaaS concept in smart communities. The digital ecosystem is designed based on system design approach. Findings from this study provides a sustainable policy perspective, discusses the challenges and opportunities towards the development of eMaaS and its impact on electrification of vehicles. Overall, findings from this study considers the role of electric vehicles as part of the mobility sharing economy. Recommendations from this study provides designs and strategies for eMaaS, the interrelations between eMobility and other everyday practices, strategically highlighting the positive benefits of eMaaS and broader policies to limit private car usage in cities.

1. Introduction

This transportation sectors reliance on private cars is unsustainable as privately owned cars are expected to be used only 5% of the time during a day, and majority of the time, it only has a single occupant (Petersson, 2020). To contribute towards addressing the climate goals, many efforts are now being directed at making the transport sector less carbon dependent and more energy efficient. Further adverse impacts such as air pollution, carbon emissions, traffic and noise accidents pose risks to the wellbeing of residents of cities and the planet, highlighting the need for efficient, clean, and sustainable modes of travel that will impact the progress of cities in the long term (Petersson, 2020). Due to digitalization, mobility is disruptively changing with the consolidation of the sharing economy, allowing novel models, such as Mobility-as-a-Service (MaaS) (Daniela, Juan Carlos, & Javier, 2022). The concept of MaaS has emerged over the years as a scheme that provides an innovative mobility model to that which combines various transport modes towards offering users with the possibility to travel from point “A to B" in a personalized, on-demand, flexible, and seamless way via single interface (Reyes García, Lenz, Haveman, & Bonnema, 2019). MaaS offers user-centred mobility service from a multimodal viewpoint by providing integrated transport services such as digital travel information, facilitating a payment option, and offering digital ticket for travel. Besides being based on a user-centred, integrated, multimodal, and transport service, many sources also incorporate normative goals like reducing private car usage thereby fostering sustainable transportation (Krauss,

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Moll, Köhler, & Axhausen, 2022).

In short, MaaS typically denotes the notion of a shift of car ownership to an approach based on a shared, seamless integration of travel modes, including both conventional public transport services, linked with shared mobility services such as bike, car, and ride sharing, and private services (Audouin & Finger, 2018; Christensen, Friis, & Nielsen, 2022). Furthermore, regarding decarbonization, "electric mobility" is one of the crucial aspects in this issue. As transportation accounts for about 26% of the total greenhouse-gas emissions in Europe. Only through integration of low-emission mobility in this sector, can overall decarbonization targets be realized (Karl, 2021). The intersection of electrification of vehicles, multimodality, and sharing can have disruptive possibility to the transport system as seen in cities today (Petersson, 2020). Findings from Christensen et al. (2022) predicted that Electric Vehicles (EVs), automated vehicles, and shared mobility are three predominant trends of innovation that are likely to have a major impact on future mobility. Equally, an increasing number of companies, organizations, policy makers, and the society are directing their attention on the use of electric mobility schemes (Anthony Jnr, 2021).

Moreover, several countries are employing regulations that promote the adoption of electric modes of transport. For instance, in the nearest future, the Netherlands (by 2030), Norway (by 2035), France and the Great Britain (by 2040), anticipate applying bans to sales of passenger cars driven by internal combustion engines (Reyes García et al., 2019). With both the growing acceptance of electric mobility and the increasing development of MaaS in cities, "electric Mobility as a Service" (eMaaS) has the absolute prospect to become one of the main solutions for today's transport challenges. eMaaS develops on the MaaS concept to provide users the option to go from one location to another not only in a seamless and multimodal medium but also in an even more environmentally friendly way (Reyes García et al., 2019). Presently the concept of eMaaS is being employed in the society as a multimodal, flexible, and sustainable technology dependent venture. With the potential of offering more convenient and a simpler cleaner transport service to users. However, this is not entirely the case today's as eMaaS practices is mostly unreliable, cumbersome, and inconvenient due to unforeseen several issues related to actors, digital technologies, and infrastructures (Anthony Jnr, 2020). Also, there is need to manage the complexity associated in the interaction with actors, digital technologies, and physical infrastructures needed for sustainable eMaaS sharing. Therefore, this research will examine the following research questions:

- What is the state-of-the-art regarding "mobility as a service", "electric mobility systems" and "shared electric mobility services" towards eMaaS sharing?
- What elements should be included to facilitate the integration, alignment, and interaction of actors, digital technologies, and physical infrastructures needed for eMaaS sharing?
- Which mobility policies are being initiated in Norway to promote the adoption of eMaaS towards sustainable transport development?

Accordingly, this study contributes to the body of knowledge by designing a digital ecosystem that enable sustainable electric mobility services in smart cities to support the actualization of sustainable transportation that aligns the synergies between mobility and energy. The digital ecosystem will enable the integration and alignment of actors, digital technologies, and infrastructures required to achieve a sustainable electric mobility sharing system in smart cities. Findings from this article inform the design of more sustainable shared and integrated eMaaS solutions with the aim of improving the adoption of (e-cars) by combining digitalization and new business models grounded on a digital ecosystem. Finding also provides evidence on how to implement monitoring, tracking & tracing, demand/offer matching, real booking & reservation management, EV status availability & delays, dynamic journey plan updates, travel/service information, pre-trip journey plans, and ticketing/billing/payment. The rest of this article is organized as follows. Section 2 introduces the theoretical background. Section 3 presents the methodology employed in this study and Section 4 presents the findings, where the developed digital ecosystem is introduced. Section 5 provides discussion and implications. Section 7 concludes this article.

2. Theoretical background

eMaaS provide a broad range of value-added service such as planning, seamless payments and providing accessible real time traffic information on demand to users. Thus, eMaaS has been considered as the major solution for future sustainable mobility (Jnr, Petersen, Ahlers, & Krogstie, 2020). Similarly, the use of electric cars will in the longer-term reduce private vehicle emissions per vehicle, since transport is still the largest emitter of CO_2, it would be important to promote the use of sustainable public transport including EV (Hensher, Nelson, & Mulley, 2022). eMaaS service providers coordinate the spare capacity of electric vehicles so as to serve the mobility needs of the public during their daily commute. As it can be the catalyst for future sustainable energy (Hensher et al., 2022), as the car batteries can become connected to energy grids through Vehicle-to-Grid (V2G) two-way charging and discharging, car fleets and car owners can contribute buffers in the energy grid for owners to become prosumers (Anthony, Petersen, Ahlers, Krogstie, & Livik, 2019).

eMaaS offers a concept that supports both current and future mobility demands of citizens, namely personalized, seamless, intermodal, and on-demand. It enables city's decarbonization-targets aimed at reducing CO_2 emissions, improves cost savings for the transport sector, and offers a sustainable alternative to reduce private car usage in cities. It builds on the concept of an integrated and seamless system providing access to multimodal mobility options, incorporating shared mobility services like e-car sharing (Jnr, Petersen, Helfert, Ahlers, & Krogstie, 2021). This will require the use of prediction models of eMaaS patterns connected the data sources, user interfaces and backends for EV users to understand how their EV uses energy and how they may impact their EV's interaction with the energy grid. For example, by stipulating limits on how much energy they are willing to share back to the grid based on their battery capacity and setting limits of how much energy charge is available on average or for the subsequent day (Ahlers, 2020).

3. Methodology

In this study a Systematic Literature Review (SLR) was adopted based on guidelines from Kitchenham and Charters (2007); Denyer and Tranfield (2009); Elbert, Müller, and Rentschler (2020); Elbert and Rentschler (2022). SLR was carried out in this study to help identify the significant literature, evaluate trends, and identify existing gaps (Denyer & Tranfield, 2009; Kitchenham & Charters, 2007).

Fig. 1 shows the review principle as suggested in the literature (Elbert & Rentschler, 2022; Kitchenham & Charters, 2007), which comprehensively comprises of six activities: formulation of research questions, specification of search strategies, identification of inclusion

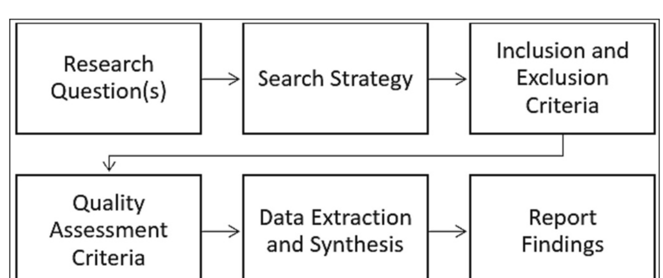

Fig. 1. Review principle employed in this study.

and exclusion criteria, quality assessment criteria, data extraction and synthesis, and report of findings. Each of these phases are discussed below.

3.1. Research questions

This study adopted a SLR to provide for exploring the development of eMaaS sharing by providing a state of the art of eMaaS and further proposes a data driven digital ecosystem as a business model for eMaaS sharing in smart cities. Overall, the research questions to be examined are presented in the introduction section of this paper. Accordingly, the research questions were operationalized in their specific facets to find the maximum number of sources relating to business model for eMaaS sharing in smart cities.

3.2. Search strategy

Based on the research question in phase one, initial keywords were derived which are unambiguous and directly derived from the goal of the study, the keyword "shared" was added to focus the search on eMaaS. To this end, an extensive search was carried out to identify studies related to data enabling digital ecosystem for sustainable shared electric mobility-as-a-service in smart cities based on an innovative business model, the search strategy was carried out using online libraries. The search was carried out from August 2022 and ended on October 2023 in Google Scholar, ScienceDirect, ProQuest, Springer, Wiley, IEEE Xplore, Emerald, ISI Web of Science, Sage, Inderscience, and Scopus as suggested by Anthony Jnr (2021). These online libraries were selected as they are considered pertinent search engines for SLRs in transportation and mobility research. Additionally, they provide options of carrying out advanced search filtering by keywords and by publication year, type, and research area. Using these online databases studies related to the study area were collected from journal articles, conference proceedings, book chapters, thesis reports, and document reports.

Furthermore, in executing the search specified keywords or search terms was used to search online electronic databases. To confirm review quality, search keywords were formulated by using Boolean AND/OR operators to combine the search terms derived from prior study (Denyer & Tranfield, 2009; Lindkvist & Melander, 2022) to improve the relevance of the search procedure. The main search terms comprise of "Mobility-as-a-Service", "electric Mobility-as-a-Service", "MaaS", "eMaaS", "shared electric Mobility-as-a-Service", "sustainable mobility", "electric mobility sharing", "green mobility", "business model", and "smart cities". *Moreover, a list of search strings was identified from* Anthony Jnr (2021) *which included "data, digital ecosystem, sustainable mobility polices, green mobility polices, data driven eMobility, and smart mobility" used to search for relevant sources.*

Fig. 2 illustrates the study selection process carried out for the selected sources conducted based on the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) as employed by prior review studies (Anthony Jnr, 2023; Elbert et al., 2020). In the early stage of the search process, 281 potential sources were retrieved from the online databases as seen in Fig. 2 using the above-mentioned keywords. 62 articles were found as duplicates and were removed. Hence, the total number of remaining articles becomes 219 which titles and abstract were screened to be in line with the study area of "sustainable shared electric mobility-as-a-service", "data enabling digital ecosystem", "innovative business model", and "smart cities". Then 51 sources were removed as the titles and abstract were not fully aligned to the study area resulting to 168 sources which is passed for the full-text assessment. In this phase, the corresponding author read all the sources and checked that their contents are related to the research question in the first phase. At the point no sources were removed. Then the 168 sources were assessed against the inclusion and exclusion (as presented in Table 1),

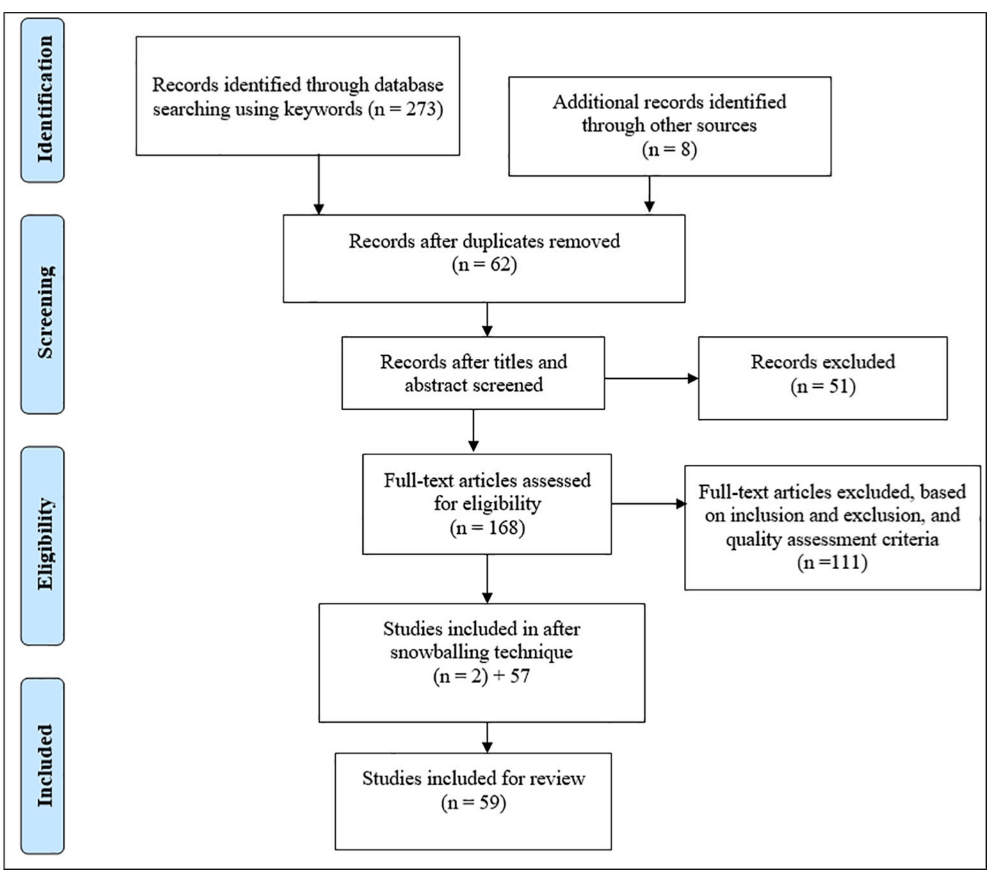

Fig. 2. Study process for the identified sources.

Table 1
Inclusion and exclusion criteria.

Inclusion criteria	Exclusion criteria
Studies published in English language.	Studies that are not written in English language.
Journal articles, conference proceedings, technical reports, and book chapters.	Not journal articles, conference proceedings and book chapters
Published between 2000 till date.	Published before 2000.
Studies that provide possible discussion and implications to research questions based on title and abstract content.	Remove duplicate/similar studies by retaining the most current and comprehensive version.
Quantitative, qualitative, modelling, and experimental studies that provides evidence.	Studies that do not provide any theoretical or practical evidence.
Studies related to the research questions being explored.	Studies not related to the research questions.
Studies related to electric Mobility-as-a-Service and Shared electric Mobility-as-a-Service business model.	Studies not related to electric Mobility-as-a-Service and Shared electric Mobility-as-a-Service business model.

and quality assessment criteria. Therefore, 111 sources were excluded as these sources did not meet the inclusion criteria. This resulted to 57 sources. After which 2 sources were added (regjeringen.no, 2021a; regjeringen.no, 2021b), based on snowballing resulting to a total of 59 sources as seen in Fig. 3 and the reference section of this article.

3.3. Inclusion and exclusion criteria

See Table 1.

3.4. Quality assessment criteria

In this phase Quality Assessment Criteria (QAC) checklists was formulated based on the recommendation of Kitchenham and Charters (2007) with respect to the aim of this study that ensures that all included studies are either indexed in Scopus or Web of Science database. This ensures that more than 50% of the included sources have been peer reviewed and published in top venues. In summary, the distribution of the selected 59 sources is shown in Fig. 3.

3.5. Data extraction and synthesis

This phase of the SLR aims to synthesize and cluster the selected sources based on their scope as related to the issues related to the research questions being investigated. The selected studies were reviewed in detail and relevant data were further extracted, analyzed, and synthesized to provide empirical evidence on "mobility as a service", "electric mobility systems" and "shared electric mobility services" towards eMaaS sharing. Moreover, data synthesis provides findings on elements that should be included to facilitate the integration, alignment, and interaction of actors, digital technologies, and physical infrastructures needed for eMaaS sharing. Lastly, the secondary data discusses mobility policies that are being initiated in Norway to promote the adoption of eMaaS towards sustainable transport development. Overall, the collected secondary data were then thematically structured in order to enable mapping across studies to provide evidence on business model for eMaaS sharing in smart cities.

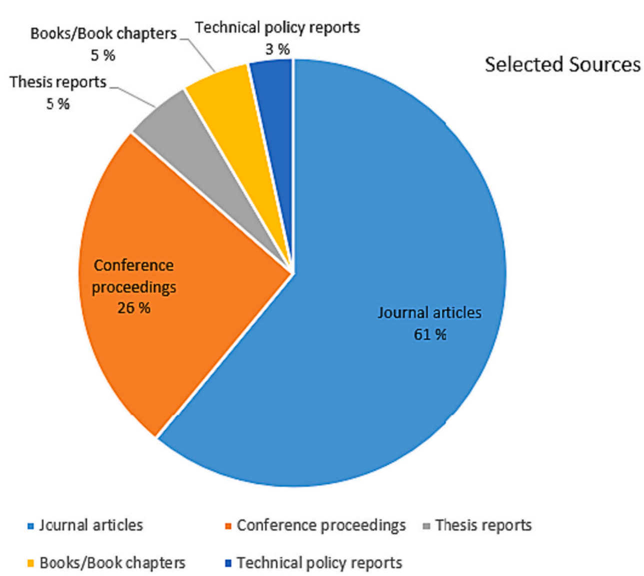

Fig. 3. Distribution of selected sources.

4. Findings from secondary data and case study

4.1. Descriptive analysis of secondary data

In the following, a descriptive analysis of the sources is conducted similar to prior research (Cavallaro & Nocera, 2022) with a focus on the following aspects: distribution of sources, year of publication, country of the publishing research institution, methodology employed, context of the study, and mobility domain.

Findings from Fig. 3 presents the distribution of the selected 59 sources, where 61% ($N = 36$) are journal articles, 26% ($N = 15$) are conference proceedings, 5% (N = 3) are thesis reports and book/book chapters respectively, and lastly 3% ($N = 2$) are technical reports on the sustainable transport development in Norway (regjeringen.no, 2021a; regjeringen.no, 2021b). The list of the journals and conference proceeding can be found in the reference list of this article.

Findings from Fig. 4 suggest that must of the included sources was published in 2020 with $N = 14$, followed by 2021 and 2022 with $N = 10$. In 2019 $N = 9$ sources were published related to the study of data driven digital ecosystem for sustainable shared electric Mobility-as-a-Service in smart cities based on a business model. This current year 2023 recorded $N = 5$ which is reasonable as this paper is written within the year 2023. 2018 and 2016 included $N = 4$ and N = 3 individually with 2007, 2009, 2013, and 2017 with $N = 1$.

Fig. 5 suggested that in analyzing the 59 sources, most of the sources included in this article are based on literature review with 29 sources, followed by case studies with 6 sources and experiments with 5 sources. Findings from Fig. 5 also depicts other method employed such as interview, simulations and modelling, and survey questionnaire both has 4 sources each. 2 sources are conceptual based, and the other remaining sources employed different methods as seen in Fig. 5. The results indicate that shared eMaaS is still an emerging topic both in research and practice and as such there is need for more evidence-based and empirical studies.

Fig. 6 shows that a total of 25 countries of the authors based on their publish affiliation(s). The results suggest that most contributors to the study area of shared eMaaS are mostly in Europe (ranging from Norway, Denmark, UK, The Netherlands), and USA as compared to other regions. A discussion on polices and measures implemented from the Norwegian context and the EV adoption success is discussed in Section 4.8. Furthermore, out of the 59 sources included in this study Fig. 7 summarizes the context explored in selected sources. The result suggests that 6 sources respectively explored mobility as a service and use of emerging technologies such as blockchain, IoT, etc. to promote shared MaaS in urban environment. Also, Fig. 7 reveal that 5 sources investigated electric mobility as a service, 3 sources explored car sharing on urban sustainability, decentralized carpooling, and electric vehicles integration respectively. Whereas 2 sources individually explored business ecosystem of MaaS, transport planning, sustainable urban mobility integration, and systematic review procedures. The remaining sources explored other areas related to mobility. However, there are fewer studies that examined how digital ecosystem can be developed as

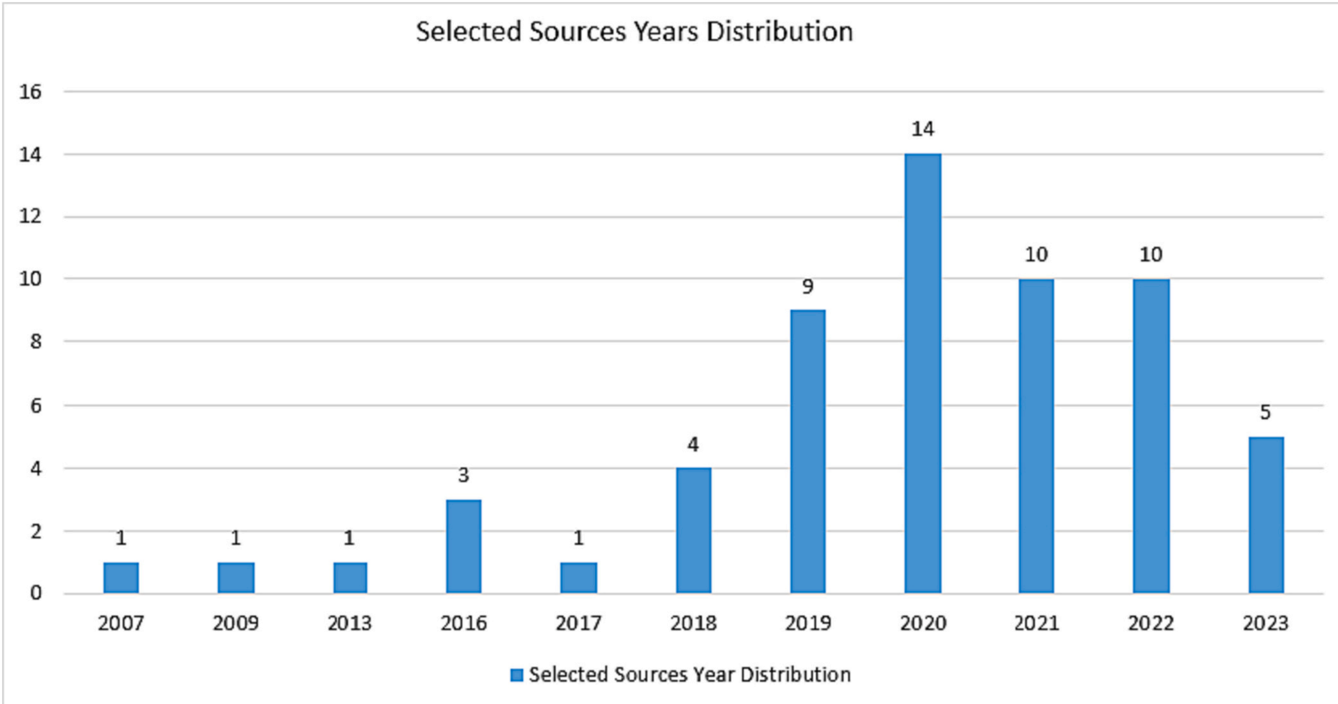

Fig. 4. Distribution of selected sources years distribution.

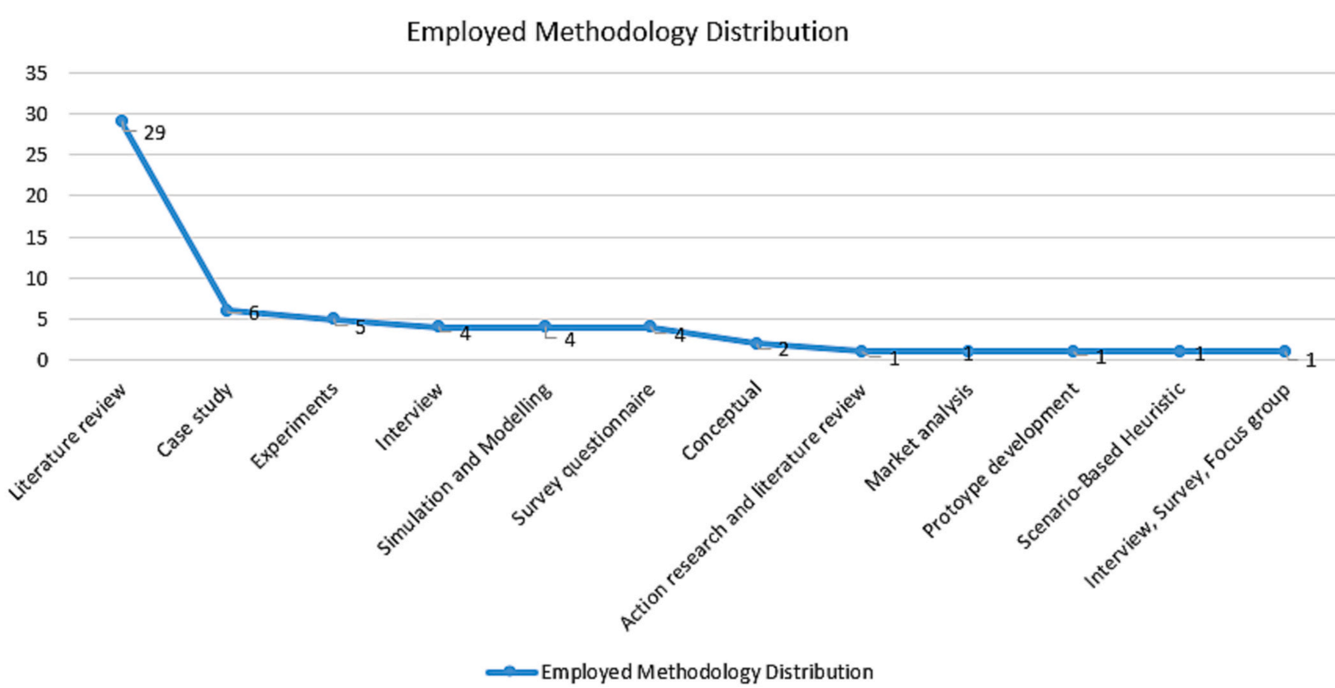

Fig. 5. Distribution of employed methodology.

business model to improve eMaaS sharing in smart cities context.

4.2. Overview of MaaS in smart cities

Presently, municipalities are face with how to improve the quality of life of their citizens. According to the report published in the 2014 United Nations (UN) world urbanization prospects, more than half of the world population resides in urban areas, and it is estimated that by 2050 about 2.5 billion people are expected to relocate to cities (Sun, Yan, & Zhang, 2016). Population increase in cities has impacted citizen's living conditions resulting to traffic jams, greenhouse gas, carbon dioxide emissions, and noise pollution. These gave prominence to the concept of smart city which has gained recognition over the past decades and is seen as a response to these environmental issues (Anthony Jnr, 2022). A smart city is typically a city that employs innovative technologies information and communications technology (ICT) and new urban

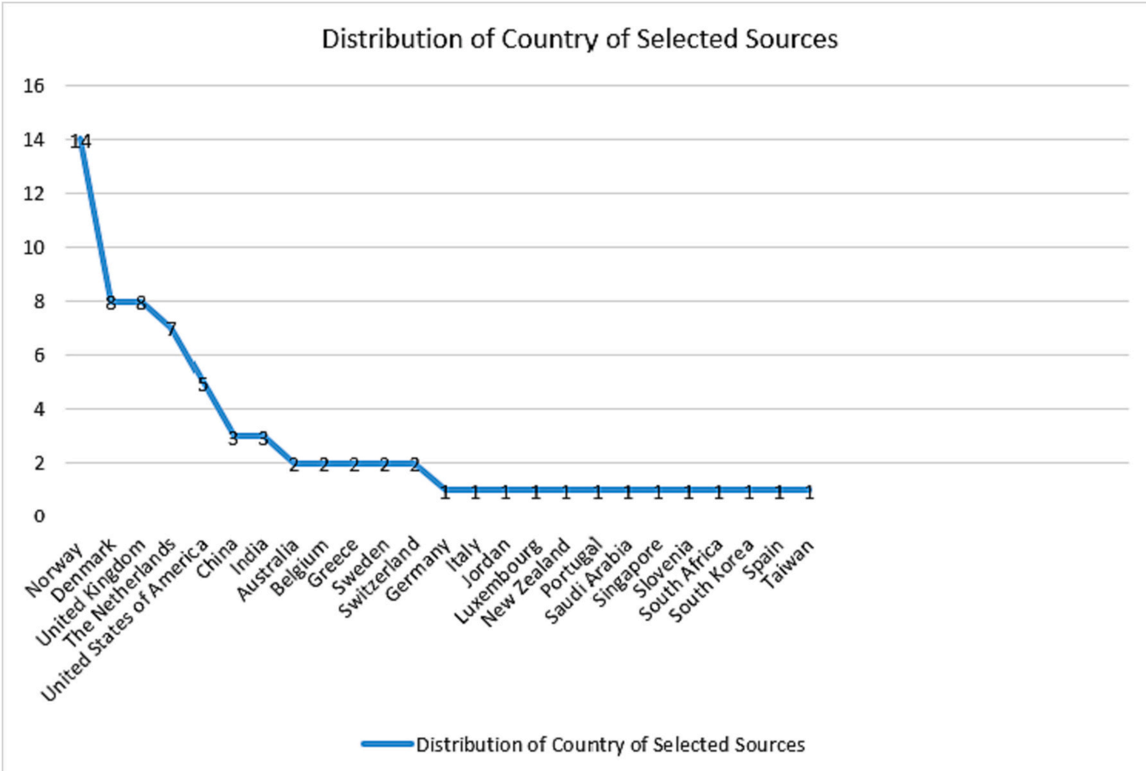

Fig. 6. Distribution of country of selected sources.

infrastructures to improve the quality of services and quality of life of inhabitants (Bokolo, 2023). In other words, a smart city refers to a complex system where human and social aspects closely interact, supported by digital technologies aimed to better utilize natural resources, decreasing wastes, and protect the natural environment (Orecchini, Santiangeli, Zuccari, Pieroni, & Suppa, 2018; Rahman et al., 2019).

"*Smart mobility for sustainable road transportation is one of the several components of a smart city*". This is due to the fact that the un-sustainable road transportation increases the number of vehicles which intensifies noise, air pollution, and traffic jams resulting to negative impact on the environment, degradation of air quality, and increasing climate change (Anthony Jnr, 2020; Khanji & Assaf, 2019). The transportation sector is one of the contributors of climate changes as the greenhouse gas emission from transportation sector in 2016 was about 25gt and is projected to increase by 2050 (Anthony Jr, 2023; Khanji & Assaf, 2019). In big cities the time spent on the road has increased exponentially by 72% over the years (Vazquez & Landa-Silva, 2021). *In this study the sharing economy is suggested as a model that can be adopted in cities to achieve a sustainable road transport.* The sharing economy refers to a social and economic model that that can be employed such as a "*community of practice*" towards "*collaborative mobility*" to make use of under-utilized cars, in which green mobility demand and supply are effectively managed (Miller, 2016; Sun et al., 2016).

One of the sharing economy schemes adopted in smart cities is the MaaS which refers to a system in which different range of mobility services are offered to customers by mobility operators. Daniela et al. (2022) defined MaaS as a distribution model that provides citizens transport needs via a single interface for a service provider by integrating different transport modes to offer tailored specified mobility services. It was also described as an intelligent user-centric mobility distribution approach in which different mobility service providers' subscriptions are aggregated by a single mobility provider who employs a single digital platform to offer mobility services such as automobiles, bicycles, scooters, motorcycles, buses, rail, monorails, trams, subways, etc. to users (Lindkvist & Melander, 2022). Fig. 8 illustrates an overview of MaaS involved in smart cities. But as the year proceeds, MaaS has evolved in a servicing period, where its less need to possess transport assets, but rather to use them, based on user's own needs.

As stated by Daniela et al. (2022) presently there are more than 60,000 mobility related apps downloaded from Google Play which provide access to both traditional public transport services and shared-mobility services, such as car-sharing, bike-sharing, moped-style, and scooter sharing services (Alyavina, Nikitas, & Njoya, 2022; Daniela et al., 2022). Also, evidence from the literature suggested the role of digital technologies to enable MaaS, either through a model or an application as a system. Accordingly, digital technologies enable MaaS to coordinate various means of transportation using digital platforms which provides available information such as timetables, availability, schedules, routes, and the traffic situation of the means of transportation available to users in real time. Fig. 8 depicts an overview of MaaS which comprises of single digital platform, intermodal/multimodal mobility services, and mobility payment schemes. A typical MaaS provider or transport operator interacts with the mobility user and mobility asset in six phases as seen in Fig. 9. The MaaS ecosystem as shown in Fig. 9 comprise of six main phases carried out in an MaaS lifecycle. The phases comprise of registration, planning, reservations, trip execution, payment, and customer support. Also, the registration and trip execution phase are based on information from operation and available mobility assets.

Fig. 9 shows the MaaS ecosystem which comprises of registration, planning, reservation, trip execution, payment, customer support. As well as the mobility operator information, and mobility asset information, each of which are discussed below.

Registration involves the authentication of the user for example driver license verification for e-car sharing mobility solution (Haveman et al., 2019). It is employed to ensure privacy and it comprises of authentication request, authentication confirmation, and possibly user ID/ authentication token (Jnr et al., 2020). *Planning* involves connection to

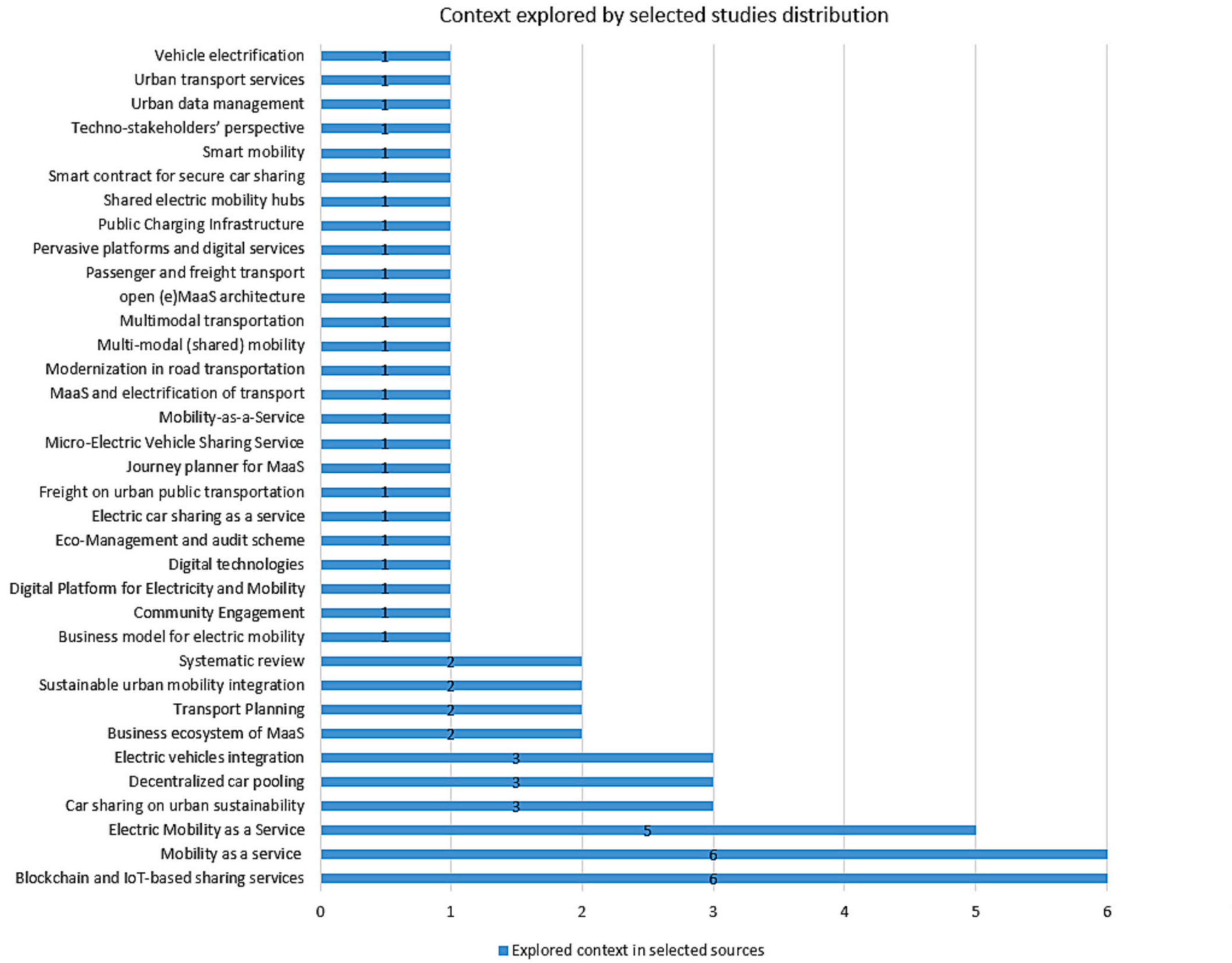

Fig. 7. Distribution of explored context in selected sources.

third party systems that provides data, check available travel options, and planning support for users to temporarily reserve assets (Haveman et al., 2019). *Reservation* comprises of booking ID/request/state/, validity token for verification via digital key/token key or e-ticket, and reservation options. The booking can be made in advance or on the go and it comprises of user authentication, booking modification or cancellation, and booking support (Haveman et al., 2019).

Trip Execution enable the user to locate mobility asset, provide specific technology access, asset telemetry, review or feedback collect and digital trip support (Haveman et al., 2019). The "*Trip Execution*" comprises of issue notification, access/pause/exit request, trip summary and monitoring based on location, distance, and duration. *Payment* may include payment journal entries and third-party payment systems, settle invoice dispute, and payment support (Haveman et al., 2019). *Customer Support* may include support request/status as well as third party support systems (Petersson, 2020). *Operator Information* comprises of transport stations and available assets, operating hours and calendar, announcement, and pricing plans. *Asset Information* is provided to support the mobility planning of users. "*Asset Information*" comprises of the availability, location, make/model/color/license plate of the mobility asset, and tariffs associated with a mobility asset. In most cases it involves the charge state/status of the mobility asset showing the state of the asset with special terms and conditions of use information (Anthony Jnr, 2021).

Overall, the MaaS ecosystem as shown in Fig. 9 comprises of different regulators & policy makers, investors, research institutes, universities, media & marketing firms, and unions who interacts with the core businesses (data provider, transport operators, and customers/users) (Kamargianni & Matyas, 2017; Loubser, Marnewick, & Joseph, 2021).

4.3. State-of-the-art of electric mobility as a service (eMaaS)

Electric mobility as a service (eMaaS) is a recent technology which is currently been discussed in industry, academia, and legislation as it is expected to shape future mobility in smart cities. eMaaS attempts to lessen urban traffic congestions and inhabitants' travel needs, by mostly encouraging low-carbon travel and shared transport mode which directly promotes sustainable transportation in an environmentally friendly way (Yu, Jin, Song, Zhai, & Wang, 2020). In smart cities e-cars are one of the cornerstones of electric mobility as the number of e-cars been used especially within European cities are significantly increasing (Abdelkafi, Makhotin, & Posselt, 2013; Anthony Jnr, 2020). Moreover, eMaaS connects EVs' sharing services to other environmentally friendly modes of mobility placing the users at the center. eMaaS involves the integration of multiple forms of electric transportation modes involving public transport and shared electric mobility services (e.g., e-scooter sharing, e-car sharing, e-bus, e-bike sharing, e-taxi), into a particular mobility service that allows citizens to plan and go from one point to another in a seamless and sustainable way.

eMaaS is accessible through a single user-centred interface and it also

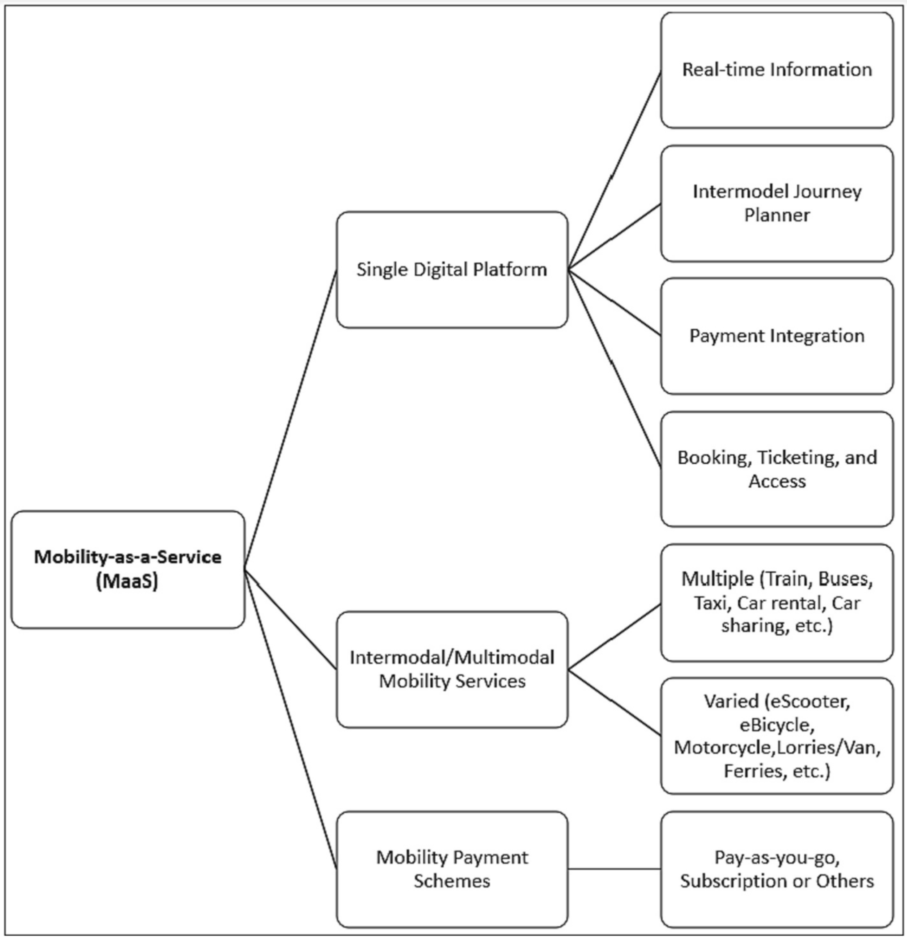

Fig. 8. Overview of MaaS in smart cities.

includes the provision of different actors, digital technologies, and infrastructure (e.g., energy contracts, charging stations, etc.) (García, Havemana, Westerhofa, & Maarten, 2020). The interactions between the digital technologies, actors, and physical infrastructure creates an interaction between the elements which embodies the electric mobility ecosystem. As such the eMaaS denotes a system of interacting actors, digital technologies, and physical infrastructures aimed at achieving a sustainable mobility by means of electricity (Anthony Jnr, 2020). This underlines that over time, the electric mobility ecosystem is anticipated to develop, grow, and adapt as new infrastructures, actors, technologies, may emerge, resulting to new interactions within the ecosystem (Abdelkafi et al., 2013). Over the decade a few studies have been published that explored eMaaS. These studies are presented in Table 2.

Evidence from Table 2 presents the author(s), year, and contributions, mobility areas explored, methodology adopted, context examined and countries of the affiliated authors institution. However, irrespective of the contributions of the reviewed studies towards fostering eMaaS, the reviewed studies did not fully examine shared electric mobility-as-a-service business model in smart cities grounded on a data enabling digital ecosystem. Likewise, only fewer studies have investigated the sustainable business model approach to improve shared electric mobility-as-a-service in urban environment.

4.4. Business schemes for electric mobility-as-a-service sharing

Presently, there are different *eMaaS sharing schemes* offered by eMaaS providers such as e-car sharing, e-bike sharing, e-scooter sharing, multimodal trip planner or multi transport integrator. The type of vehicles provided to user to enable sustainable eMaaS sharing in smart cities comprises of EVs, Micro EVs such as e-bikes, e-scooters, and Light Electric Cars (LECs) (García et al., 2020). The business ecosystem which comprises of the business models, parking models, pricing models, and payment models for eMaaS sharing deployment is shown in Fig. 10.

As shown in Fig. 10, the electric mobility assets are shared based on different business models such as *Business to Business (B2B)* where the eMaaS provider as a company offers eMaaS solution only to other companies. Another example is the *Business to Consumer (B2C)* where the mobility service provider offers eMaaS solution directly to citizens or consumers. The *Peer to Peer (P2P)* is a sharing scheme where the consumers directly interact which individuals who wish to rent out their personal electric mobility asset for a specific period via a digital platform (García et al., 2020). In this eMaaS sharing scheme the users return the electric mobility asset back to the owner in the same location where it was collected. Additionally, the *Consumer to Business to Consumer (C2B2C)* is another sharing scheme where the eMaaS provider works as an intermediate between consumers by managing and offering consumers EV to other consumers based on an EV sharing scheme (Meng, Somenahalli, & Berry, 2020). The last eMaaS sharing scheme is the *B2B corporate EV sharing* where the eMaaS providers do not provide their own shared EV fleet, instead they operate other company EV fleets based on a vehicle sharing scheme (García et al., 2020).

In relation to the *parking model schemes* offered by the eMaaS sharing for returning the shared EVs. Three main approaches are employed which includes station-based, multi-station-based, and free-floating shared EVs. In a station-based approach the EV users must return the rented EV to the same station or similar spot where it was collected from (Levina, 2016). For the multi-station-based method users can return the shared EVs at any designated station/spot managed by the same eMaaS

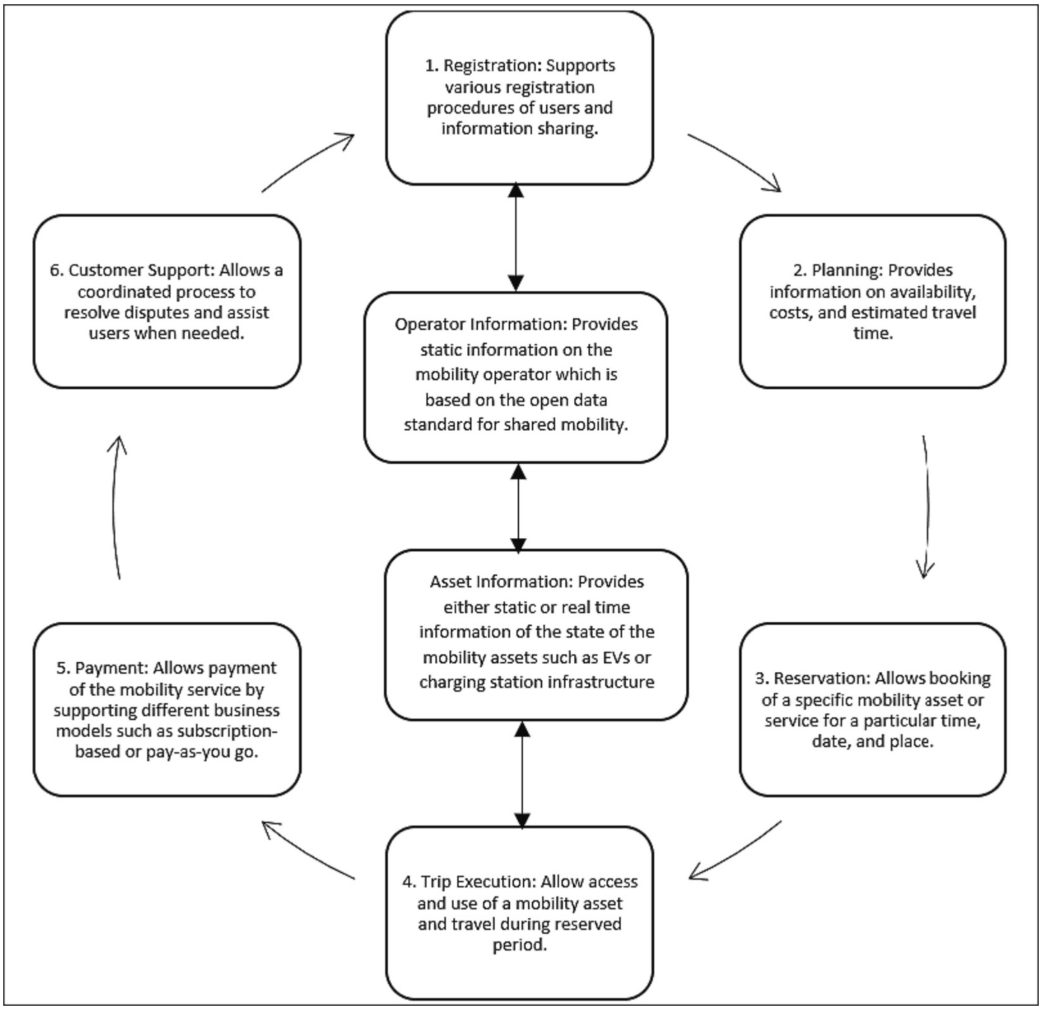

Fig. 9. MaaS ecosystem adapted from Haveman, García, Felici, and Bonnema (2019).

provider. In the free-floating approach shared EVs can be returned/parked at any location or place within the area of operation of the EVs such as use of e-scooters. Although, for EVs such as electric cars the cars can normally be used outside the specified area but must only be returned within the operational zone specified by the eMaaS provider (García et al., 2020).

Several payment schemes are adopted by the eMaaS provider which includes pay-as-you-go, subscription-based, and one-off registration fee. In the pay-as-you-go customer of the *eMaaS sharing scheme* makes payment each time they use the sharing service for their transport needs. Depending on the eMaaS provider, payment could be done in advance for instance for public transport such as e-buses, trains, etc. or after the journey/trip such as in taxi service (Münzel, Boon, Frenken, Blomme, & van der Linden, 2020). The subscription-based require users to pay a periodic fee for the use of a particular *eMaaS* and are mostly provided with some benefits and discounted fees in comparison to the pay-as-you-go approach (García et al., 2020). Another payment scheme is the one-off registration fee required in some cases users are asked to make a one-off registration fee as an additional remuneration simply paid once the first time, they are registering to utilize the *eMaaS sharing scheme*.

In addition, these *payment* schemes are based on *pricing model employed* in using EVs especially the electric cars. The pricing model are calculated based on *time, distance, both time & distance, and fixed cost.* In the "*time pricing*" mechanism, the fee to be paid by users is calculated in relation to the time the EV is used in service (Novelli et al., 2020). This could be calculated based on seconds, minutes, hours, partly daily, daily, weekend, part of the week, weekly or monthly. Depending on the eMaaS provider a certain "period of time" may be included in the start of the EV rental price. In relation to the pricing model based on "*distance*", users are required to pay based on the distance they travel with the shared EV. Depending on the eMaaS provider some kilometers can be included in the first rental price. In the "*combination*" payment scheme users are charged based on the distance and time they travel with the shared EV. Similarly depending on the eMaaS provider some minutes or kilometers may be included in the start of the rental price. For the "*fixed cost*" the pricing or cost incurred for use of the shared EV is fixed irrespective of the distance or time travelled (García et al., 2020).

4.5. Data driven eMaaS implementation

In an eMaaS implementation, different mobility services and modes may be utilized by citizens for arriving at a particular destination based on fixed mobilities (e.g., public transport and station-based e-bike sharing), while others may be based on dynamic (e.g., free-floating car-sharing and e-scooter sharing) and in the near future driverless cars (Georgakis et al., 2020). With the evolution of big data in smart cities, new opportunities have now materialized to improve mobility trip planning based on real-time data gotten from different sources (Anthony & Petersen, 2020). Examples consist of the incorporation of real-time transit data, dynamic assimilation of user produced data, and real-time forecasted traffic data to be deployed to improve daily route travel for eMaaS users (Georgakis et al., 2020). These data can be integrated as an inter-modal and multi-modal journey planner provided as either an addon or functionality with the eMaaS platform which is

Table 2
Related studies aligned to eMaaS.

Author(s), year, and contributions	Explored mobility areas	Methodology employed	Context	Countries
Bösehans et al. (2023) researched on identifying the possible early and late adopters of shared electric mobility hubs.	• Consumer adoption • Diffusion of innovation • Electric mobility • Mobility hubs • Shared mobility	Case study	Provided suggestions to policymakers and practitioners to increase the uptake of shared mobility.	The Netherlands
Hensher et al. (2022) examined electric car sharing as a service recognizing the role of the car in the shared mobility ecosystem.	• Car sharing • Electric cars • MaaS • eMaaS • Sustainability	Literature review	Aimed to improve potential future commercial pathway for MaaS subsidy from government is vital to this development.	Australia
Lee, Kim, Seo, Sim, and Kim (2022) explored satisfaction and behaviors of micro-electric vehicle sharing service from user's viewpoint.	• Micro-electric vehicles • Car-sharing • User behavior • Satisfaction	Survey, Interview	Aimed to contribute to improve the knowledge on the potential daily use of micro-EV sharing services and factors affecting usage.	South Korea
Anthony Jnr (2020) employed enterprise architecture for digital transformation of electro mobility to achieve sustainable transportation.	• Energy informatics • Electric vehicles • Digital transformations • eMobility services • Sustainable transportation • Enterprise architecture	Action research	Focused to manage data integration to support municipalities to implement sustainable mobility services.	Norway
Jnr et al. (2020) developed a data driven multi-tier architecture to support eMaaS in smart cities.	• eMaaS • Sustainability • Smart cities • Big data architecture • API management	Interview	Aimed to promote interoperability of urban infrastructures needed to allow multiple partners to data for to improve eMaaS.	Norway
García et al. (2020) presented a business model for shared electric mobility field.	• Business Model • MaaS • eMaaS • Market analysis • Shared electric mobility	Market analysis	Presented a market outline towards electric Mobility as a Service.	The Netherlands
Petersson (2020) researched on MaaS and electrification of transport.	• Electric vehicle • MaaS • Public Transport • Peer-to-peer • Free floating car sharing • Station based carsharing	Literature review, Interview	Carried out a study on obstacles and possibilities for eMaaS and offered suggestions for electrification of vehicles.	Sweden
García, Lenz, Haveman, and Bonnema (2019) Provided discussion on eMaaS and also provided an overview of system architectures and ecosystems.	• MaaS • Mobility system • eMaaS architecture • eMaaS ecosystem	Literature review	Designed an innovative architecture and ecosystem for eMaaS focused on the integration of electric mobility systems and MaaS	The Netherlands, Norway, Germany
Haveman et al. (2019) created efficient MaaS based on a system engineering method to design an open (e)MaaS architecture.	• Mobility as a Service • MaaS API • Systems engineering	Case study(s)	Proposed a functional system architecture to improve MaaS deployment.	The Netherlands, Norway
Levina (2016) researched on providing a digital platform for mobility and electricity.	• Digital platform • IT-architectural • Mobility to grid • Design process	Literature review	Described design principles for the deployment of an information platform needed to unify the domains of mobility and electricity.	Germany

usually in the form of a website portal and mobile app, where citizens can plan their trip. A common example of a platform is the trip planner provided by Google Maps (García et al., 2020).

Thus, eMaaS needs to be facilitated by an intermodal and multimodal journey planning addon that can manage the complexity requirements associated with orchestrating and governing the different mode of travel within and across cities. Prior studies have employed different techniques such as fuzzy logic, simulate annealing, heuristic-based approach, and analytical hierarchy process to optimize multimodal and intermodal planning, and computing routing methods for walking, bicycle, car, car-sharing, public transportation, and bike-sharing. Irrespective of these techniques employed by prior studies research that are focused on how data from different sources (real-time data, historical data from timetables, data from third party sources), can be integrated and assimilated in an interoperable method to support eMaaS in smart cities are still uncertain. This is because prior approaches lack the flexibility to dynamically apply data driven design methodology.

Based on the shortcomings of existing methods there is need to develop a data driven digital ecosystem for eMaaS sharing in smart cities. This will support users to manage their intermodal and multimodal journey planning by providing different services and modes to generate a valid route from an origin to a destination. A data driven

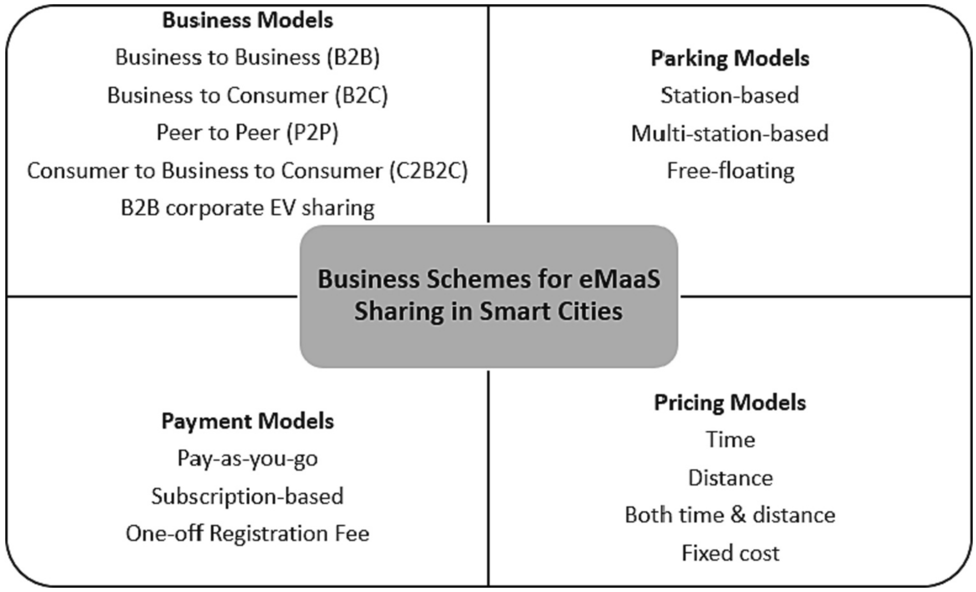

Fig. 10. Business ecosystem for eMaaS sharing deployment in smart cities.

eMaaS will support users in their everyday mobility needs more particularly related to their transportation decisions thereby providing a personalized eMaaS. The data driven digital ecosystem comprises of a logically structures grounded of available eMaaS elements of actors, physical infrastructures, and digital technologies conceptualized as an architectural design.

4.6. Systems design approach

To develop the digital ecosystem for the eMaaS sharing which comprises of an interoperable, integrated, and aligned actors, digital technologies, and physical infrastructures, this study argues that a systems design perspective is to be employed. For an eMaaS sharing solution, this requires the description and understanding of the relationship among the eMaaS elements. A common design method for the design of information systems is "*Systems Engineering Approach*". Systems engineering provides a holistic method for the design of large-scale complex social systems. It offers both specific tools as well as a "*System Design*" thinking method. In this context systems refers to an integrated set of elements, assemblies, or subsystems that achieve a defined objective. These elements consist of products (software, hardware, firmware), people, processes, techniques, information, services, facilities, and other support components. This will help for the understanding and description of the digital ecosystem. Thus, a system design methodology must establish a multitude of ways regarding how to design and visualize systems components and relationships (Haveman et al., 2019). To develop the data driven digital ecosystem for the eMaaS sharing, a systems approach comprises of five main phases as seen in Fig. 11.

As seen in Fig. 11, in the context of this study the five phases of the systems design perspective for designing the digital ecosystem for the eMaaS sharing to enable sustainable transportation in smart cities. In the first phase the context of the digital ecosystems is clarified grounded on the literature and similarly relevant actors involved in the eMaaS sharing and their respective objectives are identified from prior studies as discussed in Section 4.1.2. The second phase involves an inventory of the functions that are required to achieve existing objectives (in this study eMaaS sharing), as specified in the first phase are identified based on the digital technologies and physical infrastructure deployed to facilitated eMaaS sharing. The third phase involves allocating the specified functions as related to eMaaS sharing to a certain structure or layers (which in this study involves the "*mobility as a service*", "*electric mobility systems*" and "*shared electric mobility services*", resulting in a blueprint for a system architecture.

The fourth phase mainly involves defining the main elements (*digital technologies, actors, and physical infrastructures*), within the eMaaS sharing system structure as well as the interfaces and relationship among them. The last phase involves evaluating the system architectural design to make possible iterations towards improved optimal design of the eMaaS sharing solution. Overall, the system design approach is based on an iterative process. Moreover, Fig. 11 presents possible system design tools and techniques that can be employed. In this study a block diagram is employed to show the components for *mobility as a service*", "*electric mobility systems*" and "*shared electric mobility services*. In this study a block diagram is employed as seen in Fig. 12 for the final phase. A block diagram provides a diagrammatic representation of principal functions or parts are exemplified by blocks either without lines or via connected lines to show the relationships among the blocks. This modelling approach is heavily used to represent process flow diagrams, software/hardware design, and complex systems in the society. The block diagram is therefore used as it offers an independent architectural model that supports the visualization, description, and analysis of architecture type of design within and across industry domains. It supports

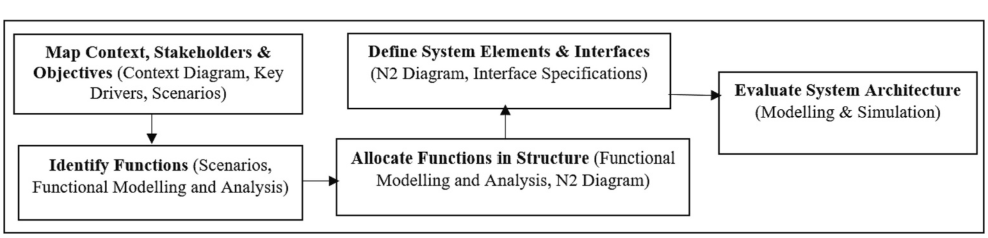

Fig. 11. System design approach.

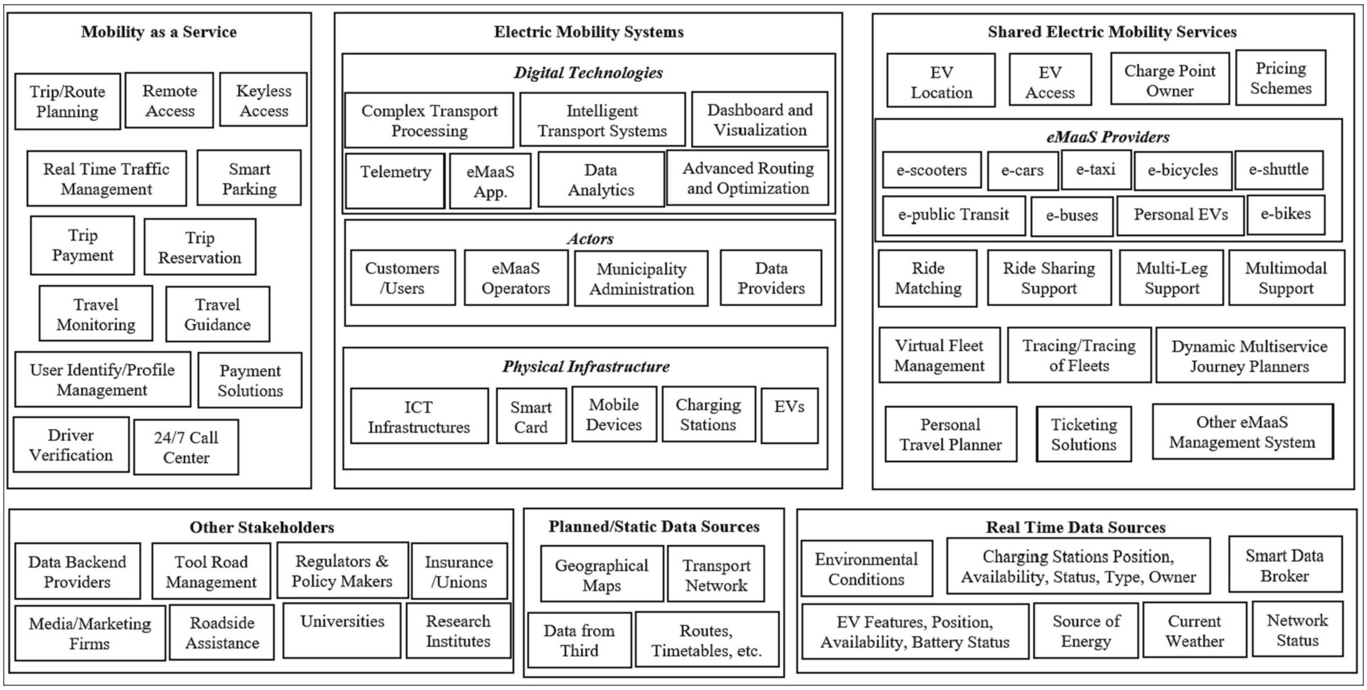

Fig. 12. Designed digital ecosystem for eMaaS in smart cities.

stakeholders in evaluating the impact of information system design choices and changes and fits well with the overall mission of eMaaS sharing in smart cities.

4.7. *Developed digital ecosystem*

Cities are progressively working towards an electrification of vehicle fleets to decrease emissions from vehicles and achieve zero emission goals. EVs are becoming increasingly popular, thus there is a growing demand for EV worldwide, and it is predicted that 30% of cars sold worldwide can be electric in 2030. The widespread use of EV with other trends such as shared mobility business models and autonomous driverless cars can deeply reshape mobility in the future, as eMaaS supports an on-demand model of transportation customized for users with zero emissions (Petersson, 2020). Overall, the digital ecosystem for eMaaS in smart cities comprises of "*mobility as a service*", "*electric mobility systems*" and "*shared electric mobility services*".

4.7.1. *Mobility as a service*

The MaaS module ensures a user-centred, seamless, multimodal, data-driven, on-demand and single platform is employed for MaaS operation. For MaaS to contribute towards eMaaS the transport service providers and transport operators must provide electric mobility solutions and electric mobility infrastructures. Moreover, regulations and policies should also be adapted to fit the electric mobility context (Reyes Garcia, Lenz, Haveman, & Bonnema, 2020). MaaS as discussed in Section 2.2, comprises of user, mobile application, MaaS provider, and transport operators for bike/scooter, carsharing, on demand bus, car rental, taxi, trains, ferries, among others.

4.7.2. *Electric mobility systems*

The electric mobility systems component brings the first part of the environmentally friendly perspective of eMaaS, as it involves the interaction of *actors, digital technologies,* and *physical infrastructures* aims at achieving a sustainable transport by means of electricity (Reyes García et al., 2019). The electric mobility systems comprise of *digital technologies, actors,* and *physical infrastructures.*

4.7.2.1. Digital technologies. Digitalization of the transport sector creates the possibility for mobility providers to derive deeper insights via available data to optimize eMaaS schemes provided to citizens (Anthony Jnr, 2020). Digital technologies play a crucial role to support the functionality and quality of service of eMaaS (Reyes García et al., 2019). In other words, eMaaS combines intelligent technologies with business model to realize technology-enabled transport service (Yu et al., 2020). New technologies interactive voice technologies play an essential role to improve the electric mobility system and to make e-cars a preferred means of transportation (Abdelkafi et al., 2013). At present distinct *digital technologies* are being employed in the mobility sector for digitalization of transport solutions (Duggal et al., 2021). Technologies like Augmented reality (AR), mobile network, edge computing, Artificial Intelligence (AI), big data, vehicular networks, Distributed Ledger Technologies (DLT), Internet of Things (IoT), digital twins, etc., are possible technologies that can support achieving sustainable digitalization of mobility services in smart cities (Yu et al., 2020).

The application of digital technologies for providing mobility related services can help in the decrease of vehicular traffic and associated carbon emission by providing monetization/incentives for car sharing/pooling thereby reducing number of cars on the road. The electric mobility ecosystem comprises of different *digital technologies,* Application Programming Interface (API), and digital platforms, that support communication management, energy generation, distribution, and storage of electrical energy. Mobility websites and digital platforms as Mobile app are installed in smart devices to provide eMaaS access for users. These mobility sharing services enable trip planning, trip booking or reservation, trip payment, EV location, EV access, etc. Also, other digital technologies enable "keyless access" or "remote access" to the EV via smart card, mobile phone, or smart lock for the shared EV (García et al., 2020).

4.7.2.2. Actors. The eMaaS ecosystem is established based on the cooperation of *multiple stakeholders and actors*. In future it is expected that the eMaaS market can be anticipated to be a collaborative marketspace, where sharing resources such as EVs, charging stations, data is expected to considerably increase in the coming years (García et al., 2020). Thus, the ecosystem is formed based on the collaboration of different stakeholders and *actors* such as charging point operators (CPOs), eMobility providers, eco-friendly transport operators, non-electric transport operators (buses, taxi, etc.) energy providers, suppliers, car manufacturers, communication companies, governments/municipalities, and customers/users (Reyes García et al., 2019). While all actors have several goals and self-interests, they collaborate with each other to achieve a competitive advantage and ensure the actualization of the electric mobility system. As the usage rates of shared EVs in the society increases, the reliant on available charging infrastructure is important for operationalization of eMaaS in smart cities (Petersson, 2020). In addition, as suggested in the literature the actors and digital technologies also includes, *mobile application provider, public transport & original equipment manufacturers (OEMs), payment engines, mobile ticketing, traffic flow monitoring, platform technology provider, and connectivity provider*. The successful deployment of eMaaS will clearly depend on how actors address challenges such as high product variation, instable markets, ambiguous user preferences, and technical uncertainty. This is because when a technology first emerges most actors are unsure about the development trend (Abdelkafi et al., 2013). Accordingly, Table 3 describes the key actors in a car sharing ecosystem.

4.7.2.3. Physical infrastructure. The *physical infrastructure* is another element that is needed in the electric mobility ecosystem. It comprises of stationary and non-stationary physical devices such as (EV-)roads, mobile device, Electric Vehicle Supply Equipment (EVSE), EV charging stations and electricity grid/power plants (Reyes García et al., 2019). Within the EV it also comprises of the telemetric systems which supports efficient energy use and appropriate billing (Abdelkafi et al., 2013). The protocols such as *IEC/ISO 15118 protocol, open charging point interface (OCPI)* employed by these physical infrastructures such as the EV chargers are also considered in this element. The physical infrastructures may include *smart battery, quick interface stations,* drivetrains, *renewable energy sources* (e.g., PV panels, wind turbine farms, hydropower plants, smart network, etc.). *Physical infrastructure* enables the use of digital technologies by actors and facilitating eMaaS. The physical infrastructure builds upon existing infrastructure in the energy and transportation sectors based on needed adjustments tailored fitted for the transport environment (Reyes García et al., 2019).

In smart cities the physical infrastructure component is faced with challenges related to establishing an efficient and easy access to energy sources, while providing access to public EV charging stations and ensuring an appropriate billing method for users (Abdelkafi et al., 2013). This component also includes use of digital technologies which is required for the development of the smart grid which allows EV users to buy cheap electricity as grid to vehicle *(G2V)* or vehicle to grid *(V2G)* integration where EVs fleets can be used for storing electricity in the energy distribution process. Hence, creating monetary gains to EV users who discharge EV batteries into the energy grid during peak hours thus creating new business opportunities (Anthony Jnr, 2021). As well as Vehicle to vehicle *(V2V)* where eMobility assets such as e-buses or e-cars fleets are used to charge micro-eMobility assets such as e-bicycles and e-scooters.

4.7.3. Shared electric mobility services

The sharing economy enables entities to share their respective assets for economic gain, assisting others who temporarily require these assets (Madhusudan, Symeonidis, Mustafa, Zhang, & Preneel, 2019). Although the emergence of the sharing economy has had a major impact in the society (Roblek et al., 2021). Road transportation is a significant field for the sharing economy (Chang & Chang, 2018). The sharing economy enables both individuals and organizations willing to share their underused tangible and intangible resources with others to effectively decrease resource waste via redistribution. In terms of sharing these resources or service such as EV sharing, the more individuals participate, the more benefits such sharing scheme may create to the overall contributors (Anthony Jnr, 2021). As suggested by Kalczynski and Miklas-Kalczynska (2019), there are two main modes for car sharing/carpooling which includes *"To/from"* mode and *"Pick up/drop off"* mode.

The *"To/from"* mode entails when the driver of the car picks up passengers on his/her way to a common destination (e.g., a, school, workplace, etc.) and later dropping off the passengers at their personal locations before returning to his/her own origin. Whereas the *"Pick up/drop off"* involves the driver picking up passengers on the way to a common destination and drops the passengers off at the destination and returns to the starting point (or goes to the destination to pick up the passengers and then drops the passengers off on the way back to the origin) (Kalczynski & Miklas-Kalczynska, 2019; Pallevada, Kanuri,

Table 3
Key actors in a car sharing business.

Actors	Description
Car manufacturers	The role of car manufacturers is important in any car sharing business model as they provide cars needed. Due to change in the mobility landscape car manufacturers are now embracing car sharing to catch up with this trend. This was observed when BMW Group and Daimler AG formed a joint venture towards pooling their existing mobility services into a fleet of over 20,000 cars within 30 cities for car sharing services (De Troch, 2020).
Mobility service providers	The mobility service providers manage the digital platform where the car sharing system is operated. They guarantee that the car renters have access to the mobility related services based on an agreed fee which is used to cover the running costs and to provide quality mobility service. The mobility service providers ensures that the digital platform enhanced user experience and resolve any disputes between participants (car owners, drivers, passengers, etc.) (De Troch, 2020).
Car owners	The car owners are individuals that share their car for a certain period of time in return for a fee. The car owners can be someone who owns a second car which is less used, or occasionally drives their car, or may reside in a neighborhood with a good multi-modal mobility system (De Troch, 2020).
Car renters	A car renter is the individual who borrows the car for a certain period of time. For this individual it is more appropriate to have regular access to different or same car than actually owning a car. The car renter is changed a certain fee which depends on how long he/she uses the car (De Troch, 2020).
Insurance providers	Insurance providers are involved in the car sharing ecosystem to satisfy regulatory compliance. In regions such as in the EU the vehicle must be insured to be rented out. Also, the car owner is responsible to insure the vehicle. This certainly depends on regulation, which entails country-specific changes that are best managed by specialized insurance businesses such as AG Insurance, Allianz, etc. which offer insurance packages for car sharing (De Troch, 2020).
Authorities	Authorities mostly involves law enforcement that may have access to encrypted data needed to solve crimes in case of any incident or abuse during car sharing. Although this may lead to privacy/security for users of the car sharing system. The involvement of the authorities may be necessary for investigation in case a serious crime was committed (De Troch, 2020).
Original Equipment Manufacturers (OEM)	OEM refers to firms that produces non-aftermarket equipment and parts that may be sold by a different manufacturer. Traditionally these are companies whose products are utilized as components in the final products of another business, which then markets the finished product (e.g., vehicle), to users. The European car sharing sector hosts a number of local and global OEMs players (Roblek, Meško, & Podbregar, 2021).

Posina, Paruchuri, & Chinta, 2021). The provision of shared electric mobility thus increases the effect of positive environmental impacts. Besides, as stated in the literature (Roblek et al., 2021), automobile companies are now launching their own electric car sharing schemes, and they have done so essentially to invent innovative ways to manage congestion and change user attitudes. Findings from Roblek et al. (2021) revealed that about 45% of car sharing providers in Europe now operate a 100% electric fleet and this mobility trend is growing. Experts argue that electric car sharing paves the way for widespread adoption of electric vehicles.

Shared electric mobility offers an environmentally friendly innovative transportation approach that supports short-term access to transportation modes for citizens based on an as-needed basis. This is characterized by the sharing of electric mobility assets such as e-car sharing, e-bike sharing and e-scooter sharing instead of owning the electric mobility asset (Islam, Moawad, Kim, & Rousseau, 2019). To achieve the digital technologies that supports vehicle sharing are utilized to connect mobility providers and users. This contributes to the economic, social, and environmental transport-related benefits (Reyes Garcia et al., 2020). The electric mobility assets may include *micro-mobility* (for 0–5 miles) mostly e-bikes and e-scooters, *medium distance* (for 5–15 miles) mostly ride hailing taxi, and lastly *long distance* (for 15+ miles) mainly car sharing schemes. The payment model can be based on *membership-based, non-membership, peer-to-peer (P2P), for-hire service, and mass transit services* (Reyes Garcia et al., 2020).

- Membership-based comprises of e-car sharing, e-scooter sharing, e-bike sharing, e-bus sharing, e-ridesharing, and e-ride hailing.
- Peer-to-Peer may comprise of e-car sharing, e-scooter sharing, and e-bike sharing.
- Non-membership-based includes e-car rental and e-limousine rental.
- For-hire ranges from e-car/bike/scooter sharing, e-ridesharing, and e-carpooling.
- Mass transit systems which include e-public transport, airport shuttles, trains, and ferries.

Overall, eMaaS facilitates users transition from EV ownership to mostly usage. Shared electric mobility enables this transition and electrifies all transportation modes towards sustainability. Accordingly, most of private and personal vehicle ownership is replaced by fleet vehicle ownership managed and maintained by the transport provider or in some cases the municipality (Reyes Garcia et al., 2020). Therefore, by providing these transport modes in combination to form an intermodal and multimodal journey users will be empowered to travel, reduces CO_2 emissions, lessen cost incurred from owning vehicle, and lessens traffic congestion faced by cities (Hensher et al., 2022). However, the goal of eMaaS can be achieved by having a well design digital ecosystem as a system architecture which captures and shows how all the important elements integrate, align, and interact in a manner to support sustainable transportation in smart cities. Therefore, Fig. 12 depicts the designed innovative digital ecosystem that aims at supporting the development of eMaaS towards sustainable transportation in smart cities.

Fig. 12 illustrates the designed digital ecosystem which is represented as a system architectural design which specifies the system and infrastructure components, relationship, associated functions, potential users, and the environment deployed to meet the goal of sustainable shared eMaaS ecosystem in smart cities. The digital ecosystem offers conceptual references to describe the capabilities, functions, and requirements of components within the eMaaS ecosystem. It also provides an easy and standardized architectural model to aid the integration, alignment, and interaction of actors, digital technologies, and physical infrastructures needed for sustainable eMaaS. In comparison to prior approaches in the literature, the digital ecosystem offers an open architectural design reference that can be employed as a supporting pillar as baseline to benchmark and assess further advancement of eMaaS in smart cities. Besides digital ecosystem is based on the building blocks of "*mobility as a service*", "*electric mobility systems*" and "*shared electric mobility services*", other stakeholders, planned/static data sources, and real time data source.

4.8. Mobility policies and EV adoption in Norway

Currently, Norway is one of the countries in the world that has more EVs per capita as 54% of all new cars purchased in Norway in 2020 are electric. Also, more than 12% of Norway's total car park have electric infrastructures for charging EVs. Likewise, the highest sales of electric car in Norway were recorded in 2020 which is due to various factors such as the subsidization of taxation rules and incentives as the main motivations for the high penetration of EVs in Norway. Furthermore, other factors included exclusion of VAT and purchase tax which provided economic incentives for potential buyers of electric cars. Other benefits involve no road toll, use of bus lanes, free parking on some municipality parking spaces, and free entry to ferries connecting national roads (regjeringen.no, 2021a). In addition, the Norwegian government encourages a market-driven expansion of charging infrastructure. In the initial phase the government established fast charging systems throughout Norway (regjeringen.no, 2021a).

At present time, more than 17,100 publicly available charging points are currently operational within Norway to support electric car usage (regjeringen.no, 2021a). This is because the Norwegian government has an ambitious goal for decreasing emissions from the transport sector and that new light vans and passenger cars sold should be zero-emission by 2025. Also, all new municipality buses should use biogas or be zero-emission by 2025 (regjeringen.no, 2021a). These goals are reliant on sustainable innovations such as eMaaS sharing, thus making zero emission technologies competitive as compared to the internal combustion engines. Moreover, to improve sustainable mobility "*The National Transport Plan 2022–2033*" was submitted to the Storting (Parliament) in March 2021 which has been setup towards the actualization of zero local emission for all new urban buses, cars, and light commercial vehicles (regjeringen.no, 2021b).

The plan highlighted priorities and policies within an economic structure for a twelve-year period and provides perspectives towards 2050. This plan will make travelling easier and increase the competitiveness of business and industry. The plan will reinforce the global Sustainable Development Goals and Norway's climate and environmental ambitions (regjeringen.no, 2021b).

Fig. 13 depicts the National Transport Plan 2022–2033 in Norway in line with the economic, technological, environmental, and social dimensions of sustainability. The National Transport Plan 2022–2033 aimed to achieve an efficient, safe, and environmental-friendly transport system in 2050 by getting more value for money, efficient use of new technologies, Vision Zero for road traffic fatalities and serious injuries, making travelling easier and increase the competitiveness of business and industry by contributing to Norway's fulfilment of its climate and environmental goals. The National Transport Plan 2022–2033 provides for considerably stronger efforts in developing and implementing innovative technologies in the transport sector. Research, development, piloting, and innovation are important elements towards this strategy (regjeringen.no, 2021b). Likewise, there has been regional policies centered strongly on lessening fleet emission towards the green energy transition. For example, cities in Norway have greater ambitions to achieve this goal. In Norwegian cities such as in Trondheim the municipality had the "Urban Environment Agreement" from 2016 which declares a "zero growth goal" to support personal transport of citizens to be covered by road transportation, walking, or cycling to reduce driving across the city (Ahlers, 2020).

Further strategies included he municipality's transport department improving the city's bus system with more than 40 electric buses, with a bus rapid transport system with 3 main routes, upgrading of bicycle paths, alongside a revised transportation strategy. Already 13.5% of EVs

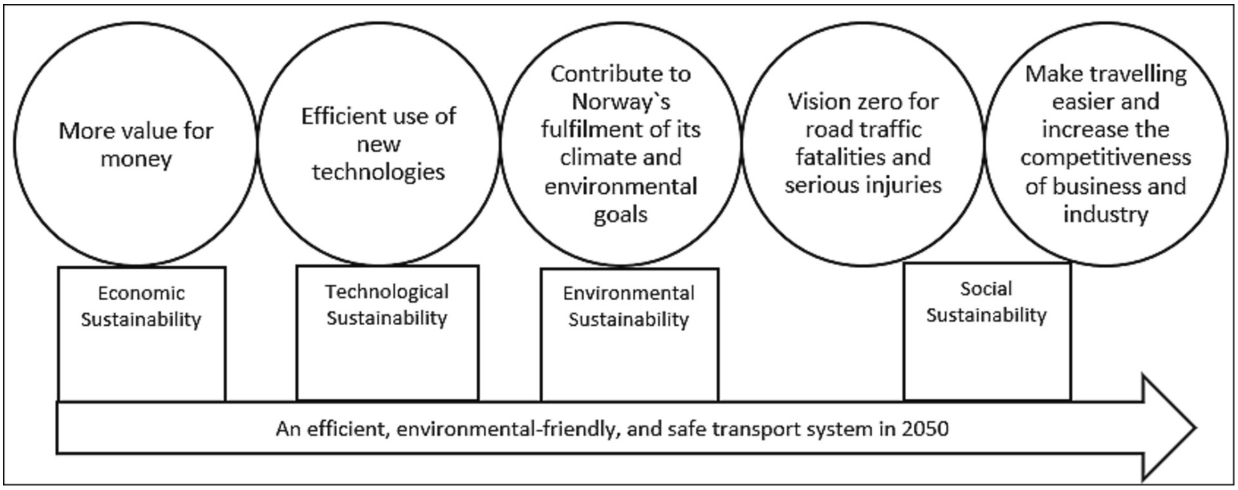

Fig. 13. The National Transport Plan 2022–2033.

are chargeable and charging infrastructures are being implemented as a fast rate (Ahlers, 2020). This study contributes to Norway's` National Transport Plan by proposing the digital ecosystem for eMaaS in smart cities which comprises of "mobility as a service", "electric mobility systems" and "shared electric mobility services" as seen in Fig. 12. This study also advocates for the deployment of digital technologies, and physical infrastructures by different actors as seen in Fig. 12. Therefore, efficiently utilizing new technologies for implementation of data driven eMaaS in smart cities (as discussed in Section 4.5), which contributes to Norway's fulfilment of its climate and environmental goals.

The implementation of data driven eMaaS in this study is well positioned with the use new technologies and research to obtain more efficient and safe transport with lower emissions. As new technologies offer better solutions for improving accessibility, capacity, and transport safety. The automation, electrification, and zero-emission mobility, with new business models are some of the drivers of smart and green transition of the transport sector. Thus, findings from this study facilitate the development of new technologies and contribute to mobility solutions and services that will help us achieve the national green urban mobility strategy. Accordingly, this study will facilitate the development of digital technologies and contribute to mobility solutions and services that will help achieve the objectives for the transport sector set by the Norwegian government.

5. Discussion and implications

5.1. Discussion

The increase of urbanization over the years and forecasts revealing that an increasing number of individuals will prefer to settle in urban areas as the year progresses this pose a challenge for transportation systems in future smart cities. At the same time, the advancement of new electric mobility services will necessitate technological solutions to support citizens with transport related tasks such as journey planning, reservation, payment, ticketing, and others (Georgakis et al., 2020). Electric mobility services such eMaaS has increasingly been implemented in cities worldwide, demanding policymakers and urban planners to adapt to and manage the overall impact of this rapidly changing form of sustainable urban mobility. Typically, shared electric mobility services are made accessed by multiple users daily and leased on a particular business model employed by the mobility service providers. These electric mobility services offer users with different mobility modes to suit their transport needs offering a means to increase the connectivity among the mobility modes to accelerate first and last mile connections (Bösehans et al., 2023). Although MaaS and eMaaS or eMobility are related. MaaS aims to decrease personal car ownership and focuses on achieving seamless multimodal mobility. Whereas eMaaS goes further towards the electrification of transportation modes and its infrastructures (Reyes Garcia et al., 2020). eMaaS sharing facilitates the transition from personal vehicle ownership to community-based vehicle sharing and usage. It enables this transition and electrifying of transportation modes towards sustainability.

The European union advocates for the adoption of alternative public transport and vehicles powered by alternative fuels such as electricity and gas (Roblek et al., 2021; Rodrigues & Franco, 2023). Accordingly, this study aims to manage electric car sharing service by developing a digital ecosystem for eMaaS in smart cities. The digital ecosystem is developed based on the system design approach to enable the interoperable and integrated sharing of a variety of electric transportation vehicles (such as e-cars, e-scooters, e-bikes, e-shuttles, etc.) both in standard electric car sharing as well as in e-ride sharing within smart cities. Additionally, the digital ecosystem supports data integration and alignment of different electric mobility services into a single seamless trip planning, reservation, execution, and payment solution. Also, in smart cities most of the private and personal vehicle ownership is being substituted by EV fleet ownership, with these EV fleets maintained, managed, and monitored via telematics by eMaaS service provider. Similarly, the designed digital ecosystem captures the need for monitoring and managing charging infrastructures required for managing shared EVs.

Overall, the digital ecosystem offers a flexible approach which can adapt to the changing digital technologies, accommodate multiple actors, vendors, systems, and physical technologies. eMaaS sharing similar to other sectors in the society are now data driven. As real time and near-real time data is generated from different sources such as the electric vehicles, charging infrastructures, operational digital systems (e.g., car sharing applications), and users who consent to sharing of their usage data regarding EV usage to enhance and optimize the eMaaS solutions offered to users (see Fig. 12). The digital ecosystem enables digital systems to collect, process and manage data (both real time data, data from third party, and static/offline batch data) from digital systems that produce data needed to enable eMaaS sharing in smart cities. Moreover, key capabilities such as advanced data analytics, opens paths to optimization, prediction, recommendations, visualization, etc. As suggested by (Reyes García et al., 2019), the digital ecosystem enables data driven functionalities.

The longer-term target of eMaaS is to achieve and interoperable, assimilated, and integrated data driven transport solution that also comprises of additional electrification of public transit (e-buses, electrified light rail), e-taxis, overall e-transportation network for car sharing companies (such as Uber, Lyft, etc.) and fleets of autonomous vehicles. Ultimately, simplifying user mobility needs from one point to another within a definite timeframe to improve users travel accessible, personalization, and preference via a seamless single payment approach possibly by using a single mobile app. The digital ecosystem sufficiently provides an extensible and future proof architectural artifact. Likewise, as advocated by prior study (Reyes García et al., 2019), the digital ecosystem captures other complementary services such as 24/7 roadside call center or assistance provided by integrated by third party actor. Value added services can be derived from the digital ecosystem to improve daily mobility of citizens on weekdays and as well as on weekends. Using the eMaaS digital platform users can book, access, pick up and return EVs via their handheld devices (e.g., smartphone application), similar to the example provided by Lee et al. (2022). Therefore, when users are returning the EV mobility assets such as electric cars, information is provided by users on how they will re-connect the electric car to available charging stations within the parking to maintain an adequate charge state for other users.

5.2. Theoretical implications

The ongoing growth of urbanization creates a real risk to the operation of transportation services in large urban areas around the world. In the wake of increasing electrification, sharing, and multimodality of vehicles there is a need to increase understanding of the interplay between actors, digital technologies, and infrastructures as key enablers to reduced emissions in the transport sector (Anthony Jnr, 2021). This article presents an investigation of the current state of the art regarding MaaS towards a digital ecosystem for eMaaS sharing services in smart cities. While the literature is fairly limited on eMaaS, prior studies provide evidence on useful conceptual references and architectures for the knowledge of MaaS environment. The digital ecosystem provides a clear overview of the main elements in the eMaaS network considering the components of electric mobility systems (such as charging points, EV fleets, etc.) and shared electric mobility services (such as electric car sharing, e-scooter sharing, e-bike sharing, and even other green mobility modes such as demand responsive transport or e-public transport).

Findings from this study is grounded on eMaaS in the Norwegian context. Therefore, the digital ecosystem designed serve as a foundation for the deployment of eMaaS and its based-on system design approach. The designed digital ecosystem provides a one-stop electric mobility sharing service which comprised of functional components and blocks that cover all the elements (actors, physical infrastructure, and digital technologies), within the eMaaS ecosystem. The digital ecosystem aims to provide easy to integrate and standardized approach that helps in the development of eMaaS solution in smart cities by identifying the stakeholders, requirements, functionalities, digital systems, data sources, and technological interfaces that need to be integrated when deploying eMaaS sharing. The digital ecosystem promotes an open environment for environmentally friendly transport system to facilitate large scale adoption of EVs through novel business models. From a business viewpoint, this work provides decision makers and managers with valuable design options on how they may adapt existing MaaS sharing schemes to the new context of electric mobility.

This study provides insight into the dynamics surrounding eMaaS (specifically electric car sharing), and our key findings signify that a further upscaling and promotion of eMaaS requires a shift in governance and policymaking towards limiting personal car-based transportation, particularly with and across cities in changing the existing cultural norm of private car being seen as the ideal transport mode. Furthermore, this study presents an exemplification of an effective business ecosystem that can be employed for eMaaS implementation in smart cities for future eMaaS providers. Such business ecosystem can be employed and used as a reference, not only by electric mobility service providers interested in joining the eMaaS market ecosystem but also by other meaningful stakeholders (such as potential users, researchers, or policy makers), who are concerned in better understanding possible business models and value proposition behind eMaaS.

5.3. Practical implications

The adoption of car sharing services where individuals choose the origin and destination of their journey is rapidly developing with the vast growth in the reputation of the sharing economy, and the adoption of car sharing services providers like Uber, DiDi, Lyft, etc. (Kanza & Safra, 2018). Car sharing is more popular when public transportation is not adequately available, particularly when longer distances are involved as car sharing can save time but most times depending on the number of passengers the travel time may extend due to some detours, which can possibly discourage individuals from participating (Kalczynski & Miklas-Kalczynska, 2019). eMaaS aims to achieve an environmental-friendly mobility previously MaaS driven by electricity. Nevertheless, the transition from MaaS to eMaaS is not merely substituting internal combustion engine with EVs but an integration of the energy grid via smart infrastructure. The connection to the energy grid infrastructure is essentially one of the strengths of the eMaaS system to support initiatives such as G2V, V2G, and V2V. Practically, the ecosystem provides “synergy between mobility and energy” by encompassing electric mobility requirements such as EV fleet management and charging points management but also integrating aspects of “mobility as a service”, “electric mobility systems” and “shared electric mobility services” for eMaaS in smart cities that is well addressed in the literature. The digital ecosystem will reinforce municipality’s goal towards developing an integrated and interoperable eMaaS architecture that promotes a modal shift towards more sustainable mobility options (walking, electric cars sharing, e-scooters, e-buses, e-bikes, etc.) and a seamless alignment of these modes for citizens journey planning and travel. This work thus serves as a steppingstone towards a supported architecture design for eMaaS sharing in smart cities. This study designs a standardized and open architectural model to optimize individual’s commute or traffic flow throughout the city by examining the routes, time/cost/traffic estimation, etc. adapting to (near) real time changes.

Moreover, while prior studies highlighted the need for availability and access to data as a key component for eMaaS for improved transportation services to citizens. Issues related to how to address the facilitate the integration, alignment, and interaction of data from various sources. For example EV data from telematics in fleets, EV booking transactions, unusual events during trips, contextual data (e.g., read conditions, weather), in an interoperable way, so that these data can be utilized to support value added services, both for eMobility service providers (e.g., for service planning optimization, data analytics and visualization of eMobility assets) and for other actors (e.g., insurance companies, municipality administration, local power utilities, policy makers, etc.) is not well investigated. The digital ecosystem attempts to improve the integration, alignment, and interaction of actors, digital technologies, and physical infrastructures needed to have an operational eMaaS sharing service in smart cities. This will help to provide contextual information on current state of smart charger’s and battery charge availability to users of EV assets such as the electric cars.

6. Conclusions

To achieve a successful eMaaS sharing service different electric mobility actors, digital technologies, and physical infrastructures will not be interoperable, unless an adequate business model is developed. This is because business model signifies the way businesses generates income, thus business model innovation such as the digital ecosystem plays an important role for achieving a high adoption of new technology, most particularly the electric car sharing for eMaaS in smart cities. Without adequate business models, businesses will find it challenging to earn revenues out of a novel technology deployed for use in the society. Accordingly, this study review existing studies to develop a business ecosystem for eMaaS sharing deployment in smart cities based on system design approach. Evidence from this study provides knowledge to businesses, researchers, practitioners, municipalities, eMobility providers on MaaS ecosystem (as seen in Figs. 8 and 9), and the overall business ecosystem for eMaaS sharing deployment in smart cities (see Fig. 10). This study contributes to existing body of knowledge by providing key implications for the future design of eMaaS sharing solutions that can be represented based on a data driven eMaaS implementation and business driven ecosystem.

The developed digital ecosystem provides a feasible business architectural model for all stakeholders showing how "mobility as a service", "electric mobility systems" and "shared electric mobility services", enabling a clear integration, alignment, and interaction of actors, digital technologies, and physical infrastructures towards the actualization of eMaaS. This helps to reduce silo for an effective multimodality and assimilation of different services which is needed to provide a sustainable transport system in future smart cities. Nevertheless, a limitation of this study is that this study adopts a systematic literature review and only secondary data was used, and the selected sources were mainly index in Scopus and Web of Science online database. In future more online libraries will be employed and there is need to further test the usefulness of the developed digital ecosystem in an innovation project. Qualitative data will be collected from electric mobility sharing service providers and individuals to further test the applicability of the digital ecosystem. The case study presented is only based on the current sustainable transportation policies in Norway as such future work will considers other European countries and other regions in the world where eMaaS is being adopted in municipalities. Also, scenario-based explorative workshops will be conducted with relevant actors and data from the workshops will be analyzed using a thematic analysis in NVivo to help categorize, analyze, and find insights within the data. Furthermore, primary data will be collected using survey questionnaire from individuals to validate the designed digital ecosystem (see Fig. 12). The collected data will be analyzed using statistical tools such as SPSS (Statistical Package for the Social Sciences) for quantitative analysis of complex data.

CRediT authorship contribution statement

Bokolo Anthony: Writing – original draft, Conceptualization, Methodology, Investigation, Visualization, Writing – review & editing.

Declaration of Competing Interest

None.

Data availability

No data was used for the research described in the article.

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