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Examining the Adoption of Sustainable eMobility-Sharing in Smart Communities: Diffusion of Innovation Theory Perspective

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Abstract: The transport sector is undergoing disruption due to trends such as tightening environmental targets, digitalization, and servitization, contributing to low-carbon mobility and offering citizen-oriented services. As a response, various initiatives, such as electric mobility (eMobility), have emerged that promote sustainable road transport and active mobility in the last few years. However, irrespective of the potential of eMobility, there are still few studies that examine individuals' intention and adoption of eMobility-sharing services in smart communities. Accordingly, this study aims to develop a model grounded on the Diffusion of Innovation (DoI) theory to investigate the factors that impact individuals' adoption of eMobility-sharing service and how to improve the adoption of eMobility-sharing service. A mixed-mode methodology was employed; quantitative data from survey questionnaires were used to gather data, and Statistical Package for Social Science (SPSS) was used to analyze the data. Additionally, qualitative data via interview was collected to demonstrate in ArchiMate modeling language how eMobility-sharing services are practically implemented as a use case study within smart communities. Findings from this study offer a model that focuses on eMobility-sharing adoption from the perspective of smart communities. Additionally, the findings offer a better understanding of how such integrated, multimodal systems fit with the sustainable mobility needs of citizens. More importantly, general recommendations to policymakers and practitioners to increase the uptake of shared eMobility are provided.

Keywords: digitalization; disruptive mobility; eMobility adoption; electric vehicles sharing adoption; diffusion of innovation; smart communities

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1. Introduction

A smart community refers to a complex system where human and social aspects closely interact, supported by digital technologies aimed to better utilize natural resources, decrease waste, and protect the natural environment [1]. Presently, the continual development of road transportation in smart communities, including car-based mobility, has resulted in increasing levels of global climate change (about 71.7% EU (Convention) share of transport greenhouse gas emissions) as reported by the European Environment Agency [2]. Thus, there is a serious need to decrease mobility-related emissions [3]. This necessitates the need for a sustainable transition of mobility [4,5]. At the frontline of this advancement lies the concept of electric mobility (eMobility), which supports the transportation of residents and tourists in municipalities by offering a solution that integrates several mobility modes, such as car-sharing, public transport, rental car, and taxi, to meet all transport needs of end users [6,7]. Findings from the literature argued that eMobility has the capability to drastically change the future of public transport [8,9]. In line with incessant efforts to decrease the need for fossil fuels, electrified vehicles have taken on an increasing part of the transport area, and predictions suggested that almost half of the cars sold in Europe can be electric in 2030 and 30 percent in the United States [9,10].

Presently, cities are promoting the growth of car-sharing fleets, particularly "first mile" and "last mile" mobility options, to improve access to public transport, which can be expanded to electric car-sharing fleets [8,11]. eMobility-sharing service, which involves electric vehicle sharing schemes where electric cars, electric bicycles (e-bicycles), electric scooters (e-scooters), etc., are rented for an agreed period, typically on an hourly, half daily, daily, or longer basis, orchestrated through a digital platform. The overarching strategy of the eMobility-sharing service is to improve car-sharing possibilities based on attractive pricing to decrease private car use and ownership [8]. However, fewer studies have provided knowledge on citizens' intention and adoption of available eMobility-sharing solutions [5–7]. Moreover, there are inadequate studies that have examined eMobility-sharing implementation and the challenges of eMobility-sharing in smart communities. The main factors that influence the uptake and adoption of eMobility-sharing services in smart communities grounded mainly on an innovation theory are not well researched in the literature. Therefore, this research will examine the following research questions:

- Which factors influence individuals' adoption of eMobility-sharing solutions in smart communities?
- How to improve individuals' adoption of eMobility-sharing solutions in smart communities?

This study contributes to the literature by proposing an innovative model that aims to support the development of eMobility-sharing services in smart communities. This model employs the Diffusion of Innovation Theory (DoI) to identify the adoption stages and related factors that impact an individual's uptake of eMobility-sharing services in smart communities. The originality of this current study is grounded on the capability of the model to pave the way for easy widespread deployment of eMobility solutions by creating a transparent design and methods to improve the sustainable mobility of citizens. Furthermore, evidence from this study presents the state of the art of eMobility and identifies inhibitors that impact the use of shared electric mobility services in smart communities. This study offers a better understanding of how shared e-mobility solutions is being implemented in smart communities for the transition toward the use of greener mobility services. The rest of this article is organized as follows. Section 2 introduces the literature review. Section 3 introduces the methodology employed in this study, and Section 4 presents the findings. Section 5 provides a discussion and implications. Section 6 concludes this article.

2. Literature Review

2.1. Synopsis of Mobility-as-a-Service in Smart Communities

A smart community is typically a municipality that employs emerging technologies and new urban infrastructures to improve the quality of services and the quality of life of inhabitants. In other words, a smart community refers to a complex system where human and social aspects closely interact, supported by emerging technologies aimed to better utilize natural resources, decrease waste, and protect the natural environment [1]. Smart community planning is mostly developed around cars, as the congestion of cars, exhaust fumes, noise, and accidents are all byproducts impacting our daily lives [1]. Mobility-as-a-service (MaaS) is employed in smart communities, where MaaS employs a single digital platform that provides mobility access via a single payment channel instead of multiple payment and ticketing operations [12]. MaaS was described as the integration of different forms of transport services into a specific mobility service made available on demand [13]. Thus, MaaS can be seen as a form of service managed through a collaborative digital channel that supports users to plan, reserve, and pay for different types of mobility services [13]. Practically, MaaS enables users to access different mobility services in relation to their transport needs. Figure 1 shows the characteristics of MaaS in making cities transport to be smarter.

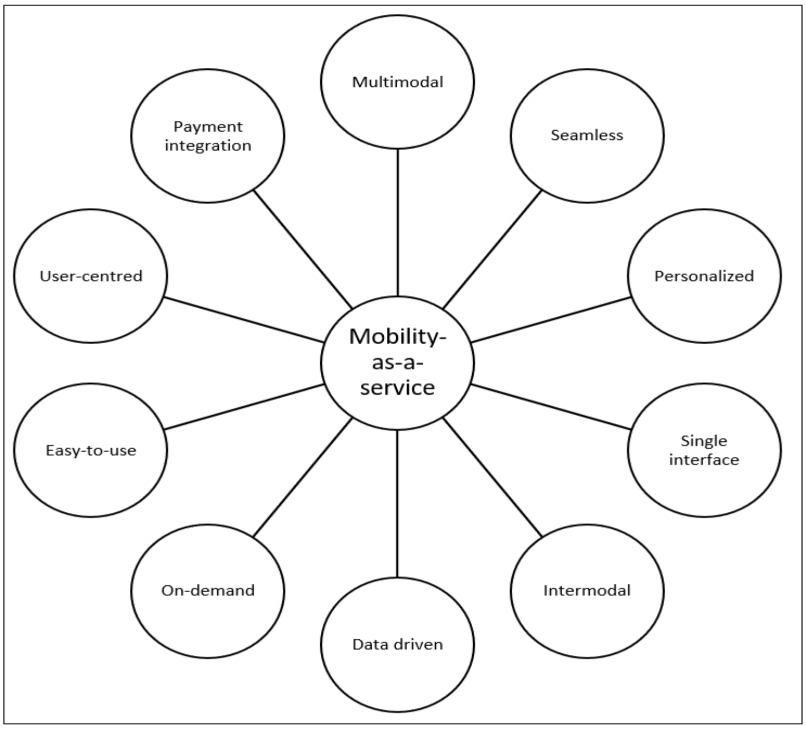

Figure 1. Characteristics of MaaS in making transport smarter.

The efficient operation of MaaS is operated by digital technologies supported by data management tools, a wide penetration of smartphones among citizens with Internet-enabled connection, and Global Positioning System (GPS) technology [14,15]. These digital technologies are used to provide data-driven service, travel insights, and value-added services to customers. Overall, MaaS is mostly user-centered, hence always considering the needs of the end-user, and mostly provides personalized service that meets the mobility needs of each individual user and customization, which supports end users to adjust the offered mobility service preference to their choice [9,16]. Figure 2 depicts stakeholders involved in MaaS within smart communities.

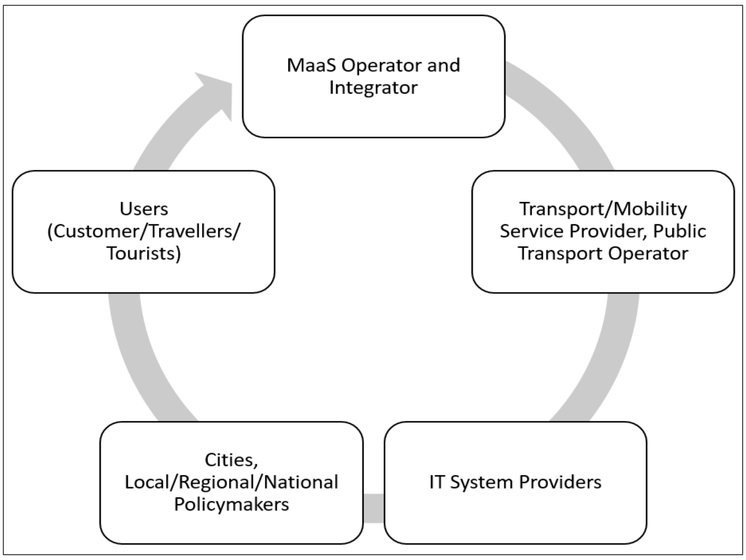

Figure 2. Stakeholders involved in MaaS adapted from Petersson [9].

MaaS comprises the integration of different transport modes to meet the demand of users as well as offering transport solutions with an emphasis on improving efficiency and providing different modes of transport [9]. The basis of a MaaS today mainly consists of various travel alternatives, as well as other services that may increases mobility experience for the user (e.g., weather forecast, road condition), etc. [9,17]. In that respect, MaaS includes a range of services that could not be accessible through one provider on its own.

2.2. Transition of Mobility-as-a-Service to Electric Mobility-as-a-Service

As with many emerging concepts, MaaS has been evolving since its early inception in 2014 in Helsinki, Finland, where municipality administrators evaluated the option to restructure the transportation supply to meet the demand of passengers with changing requirements. Initially, MaaS mainly relied on the integration of on-demand transport services provided by both private and public modes of motorized and non-motorized transportation managed by one single authority using digital technologies. The MaaS payment schemes were either based on a pay-per-trip or a subscription scheme [18]. In the beginning, MaaS typically provided transit, paratransit, and parking services, therefore supplying an integrated "niche" transport service, from taxi to car-sharing, car rental, ride-hailing, etc. But over the years, MaaS is now focused on offering a single integrated platform that combines all existing transportation services to customers as a simple solution. This is made available through an app tailored to provide both traditional and door-to-door mobility alternatives via a single payment method [19].

According to the literature, MaaS is presently operated in several municipalities mostly in Northern Europe, Australia, and North America [18], where it is possible for residents to live without a personal car due to the available MaaS, such as public transport service. In recent years, shared electric mobility-as-a-service (eMaaS) solutions like e-scooters, e-car-sharing, and e-bike sharing have gained momentum in major Nordic countries like Denmark, Norway, Germany, Finland, and Sweden, shifting the norm as regards car ownership, access, and the future for MaaS to eMaaS [5,20]. This green shift from MaaS to eMaaS across cities is aimed at promoting the acceleration of the electrification of the transportation system, as presently, electrifying road transport makes up approximately 13 percent of energy use in Europe [21]. However, eMaaS can only be successful if the business ecosystem is designed as a system that includes numerous stakeholders. The eMaaS providers and operators must collaborate with the municipality administration [22], who integrates the vehicles into the city's current traffic [1,23,24].

However, few studies have provided knowledge on citizens' intention and adoption of available eMobility-sharing solutions. Thus, there is a need for a study that investigates factors that influences individuals' adoption of eMobility-sharing solutions in smart communities and also explores how to improve individuals' adoption of eMobility-sharing solutions in smart communities.

2.3. eMobility Implementation in Smart Communities

The eMobility concept is grounded upon the eMaaS approach, which is based on MaaS, as previously stated, which aims to achieve eco-friendly, seamless, and multimodal mobility [8,9,25]. eMobility involves the integration of several forms of electric mobility modes involving road transport and shared electric mobility services, for instance, e-bike sharing, e-scooter sharing, e-car-sharing, e-bus, and e-taxi into a single mobility platform that assists citizens to plan and travel within and across cities in a seamless and eco-friendly way [26–28]. The eMobility ecosystem comprises transportation services, infrastructure, information, and payment services. In the ecosystem, the different actors and modes of transport share similar objectives of providing a seamless mobility experience aimed at enhancing the transportation network by exploiting the benefits of individual service [29,30]. Additionally, other actors, such as the municipality or companies that provide e-cars or charging station infrastructures, can also collaborate to improve mobility operations. A typical eMobility ecosystem comprises service providers, a business-to-business-enabled platform, eMobility retailers, and travelers.

The ecosystems level also consists of the public and regulatory level, the transport and logistics service providers level, the eMobility service level, and the end-user level. In the ecosystem, the supply side comprises the transport and logistics service providers level, whereas the demand side is linked to the user interface. The public and regulatory level and eMobility service level comprise the most relevant stakeholders/actors within the ecosystem, which includes the local and national agencies (for example, the Ministry of Transport, urban planning department, and road safety agencies), and the municipality transport service providers and eMobility operator [28,31]. Evidently, mobility-sharing schemes such as car-sharing or ridesharing are one of the sustainable economic models employed in the eMobility business model. However, these mobility-sharing schemes have been criticized due to negative feedback such as safety, ride availability, and social awkwardness in most situations. Also, though these eMobility-sharing schemes have several environmental benefits, they remain strongly dependent on citizens' attitudes to replacing their mobility needs with private motorized transport with eMobility-sharing schemes as well as road transportation modes.

However, for citizens to adopt eMobility-sharing services into their daily travel routines, perceived barriers such as cost consideration and availability of shared EV, the inability to park EV where it is convenient to the user, location of the vehicle being either close to the user or not, and a possible a lack of competencies in using EVs must be considered [32]. To improve the adoption of eMobility, the EV provided should be affordable, well-maintained, clean, and safe for the users. Also, the confidentiality of users' travel data should be guaranteed by adhering to privacy regulations such as GDPR, always eMobility service providers must always have an available number of EVs with an easy registration, leasing, and payment process [33]. Lastly, there should be several locations where EVs can be accessed or left, and clear and easy-to-understand information on how to operate EVs should be provided to users [19,34,35].

2.4. eMobility-Sharing in Smart Communities

eMobility belongs to the theme of the "sharing economy", which comprises novel business models exploiting under-utilized physical assets by changing ownership by access. Karl [36] mentioned that car-sharing schemes have the potential to fulfill the customized transportation needs of individuals in a sustainable and socially beneficial way by reducing the demand for more cars in cities, thereby lowering emissions, decreasing traffic, and promoting social cohesion between sharers. Findings from the literature suggest that as many as 15 personal cars can be substituted with one shared car, and data from the Organisation for Economic Co-operation and Development (OECD) demonstrated in a simulation in Lisbon that 10 percent of the existing vehicle fleet provided via shared mobility can meet the private transportation demand of the city. It is recommended that the usage and success rate of car-sharing schemes be connected to the availability and performance of road transport [9,37].

Presently, car-pooling and car-sharing schemes are starting to change the travel habits of users by achieving a mobility shift from vehicle ownership to shared eMobility. Among the popular forms of eMobility-sharing, such as ridesharing and e-bike sharing., electric car-sharing is increasing rapidly across cities around the world [6]. Another study by Borghetti [38] aimed at defining and comparing two different scenarios: a current one, analyzing the data of the existing Free-Floating Car-sharing (FFCS) in Milan, Italy, and an evolutionary one, that foresees the renewal of the entire fleet of available cars with electric cars. The work represented a useful decision support tool for the planning and design of electric mobility in cities.

Further findings from the literature suggest that electric car-sharing has the potential to meet personalized transportation demands in an environmental way by lessening the demand for private cars and parking, thereby decreasing emissions since users of electric car-sharing schemes utilize multimodal modes of travel, which requires driving less [39]. Therefore, eMobility service providers have emerged as a key force shaping the directions of eMobility development and consequently impacting the purchase cost of electric cars and significantly decreasing the cost burden for, e.g., maintenance, insurance, and depreciation [40]. According to the literature, there is a clear paradigm shift in the transport sector with shared eMobility business models promoting temporary usage of electric cars through car leasing, car-sharing, or ridesharing schemes [36].

While shared eMobility models may not resolve all the existing road transport problems in smart communities, it offers several economic, social, and environmental benefits to society. Environmentally, it can lessen congestion through fewer vehicles on the road and pollution when electric cars are used in place of traditional combustion-based cars [41]. Socially, shared eMobility can also promote social equity if the provision of electric cars is extended to include socially disadvantaged low-income groups, thus promoting inclusive mobility, equality, and the quality of life of citizens in cities [32]. Citizens may use a shared electric vehicle for door-to-door mobility needs, addressing the first-mile and last-mile issues in a cost-effective way, thus reducing the citizens' dependence on private motorized transport and making travel more economically sustainable [42]. But there are currently limited studies to improve individuals' adoption of eMobility-sharing for long-term success within smart communities.

2.5. eMobility-Sharing Business Models

The earlier feasible car-sharing schemes started in the late 1980s in Germany and Switzerland as a small project deployed by environmental-friendly organizations based on a business-to-consumer (B2C) method, in which the businesses own some fleet of cars that they rent out to prospective customers. This approach was either for-profit or non-profit as the B2C business model is relatively similar and based on the Round-Trip (RT) scheme, where the rented cars must be returned to the same parking spot where they were driven after use [43]. In this car-sharing scheme, specific parking spots are often made available to the car-sharing companies by the municipality to promote sustainable mobility within the city. Around the beginning of 2009, another type of B2C car-sharing business model started to emerge where some businesses implemented a One-way (OW) system. In this scheme, the cars do not necessarily need to be returned to the location where it was driven from but can be parked within a defined area (free-floating) in the city or at a distinct station of the car-sharing provider (as station-based sharing) [39].

In 2011, a different business model for car-sharing was established based on an online peer-to-peer (P2P) system on which private car owners can lease out their private cars to other citizens or peers. In this scheme, some specified percentage or fee is allocated back to the P2P system to match the demand and supply of cars, and this scheme typically offers other services like car insurance. Although, P2P is mainly deployed in a Round-Trip approach as the car is collected from and returned to the car owner. Within the P2P car-sharing scheme, the rented cars are privately owned and less used and are only made available for public leasing when they are idle [39] as eMobility-sharing schemes like electric car-sharing provide mobility access to customers to use locally available electric cars at any time based on a predefined duration. This differs from e-taxis services as the renter drives the electric car, and it also differs from traditional car rental since electric cars are locally made available at any time and specified duration [39].

As evidence from the literature suggests that eMobility-sharing schemes reduce the number of cars in cities, it is plausible that increased availability of electric car-sharing can help boost sustainability in the transport sector [44]. Nevertheless, it is essential to understand what possible business models are suitable for eMobility-sharing schemes that can be employed for electric car-sharing to complement other transport services [9]. Within electric car-sharing, various business models have been observed, as discussed below.

- Two-way/roundtrip systems which is a scheme where the collected electric car needs to be returned to the same parking station as where it was picked up.
- One-way system which is a type of sharing where the electric car can be parked at any designated parking station specified by the mobility provider.

- The free-floating system which employs a scheme where electric cars can be freely left at any available parking station. This approach is similar to the traditional servitization system that depends on how well the municipality plans for it to well works so as to prevent parking and congestion within the street.

2.6. Related Works

A few studies investigated sustainable mobility in an urban context. The identified studies related to sustainable mobility from the literature include works as shown in Table 1.

Table 1. Existing studies on sustainable mobility in urban context.

Author(s), Year, and Contributions	Explored Mobility Areas	Methodology Employed	Context	Countries
Holota et al. [45] explored sustainable mobility in urban environment based on a multimodal approach for greener cities.	• Sustainable mobility • Multimodal travel choices • Public transport • Traffic	Questionnaire survey	Suggested multimodality as one of the solutions to address the current traffic situation, as it aids residents to select from a range of travel alternatives and its effects on mobility behavior.	Slovakia
Singh et al. [46] studied how to optimize local and global goals for achieving sustainable mobility in urban spaces.	• Stakeholder participation • Sustainable urban mobility • Multi-objective optimization • Simulation-based optimization	Simulation and optimization	Presented a method that enable collaboration of stakeholders and also presents a near optimal set of options to choose from by describing the capabilities and requirements to model local noise reduction and global emissions simultaneously.	Sweden, Germany
Echeverría et al. [47] explored countries that uses green mobility profiles.	• Green mobility • Public transport • Walking/cycling • Multinational time use study	Multinational Time Use Study data set using Ordinary Least Squares regressions modelling	Investigated the socio-demographic characteristics of users performing green travel behavior.	Spain, Argentina, The Netherlands
Julsrud and Denstadli [48] employed social practice change to explore essential factors to promote the implementation and use of electric vans in crafts and services organizations.	• Electric vans • Sustainable mobility • Social Practice Theory • Change agency • Organisational innovations	Case study Qualitative interviews	The study focuses to improve green mobility practices based on the function of change agents.	Norway
Oleśków-Szłapka et al. [49] examined sustainable urban mobility in Oslo and Poznan development perspectives.	• Sustainable transport • Urban transportation • Green mobility • Sustainability	Questionnaire	Reviewed literature on research subject, national policies, and EU documents in relation to funding and promotion of sustainable urban transport.	Poland
Ponkshe and Pricing [50] researched policymaking toward improving green mobility.	• Urban transportation policies • Sustainable and green transportation • Green mobility	Literature review	Investigates how to facilitate green and sustainable transportation and explores their limitations facing the uptake of green mobility.	India
Mateescu and Popa [51] provided evidence of European policies and measures to promote green mobility.	• Air pollution • Green mobility • Urban planning	Literature review	Provided an analysis of the best practices in planning and organizing urban transport by adopting mobility initiatives and green solutions.	Romania.
Curiel-Esparza et al. [52] presented a prioritization-by-consensus approach for sustainable mobility in urban areas.	• Sustainable mobility • Transport • Multicriteria decision making • AHP, VIKOR • Delphi method	Delphi method, Questionnaire	Presents a decision support tool to select the optimum sustainability improvement.	Spain
Szołtysek and Otręba [53] researched determinants that influence the quality of life in developing city green mobility goal.	• Mobility • Logistics • Attitudes and behaviors • Quality of life	Survey questionnaire	Identify which mobility elements ought to promote mobility in the city in order to address citizens' expectations.	Poland
Ribeiro and Mendes [54] explored sustainable mobility in urban regions of middle-sized cities.	• Sustainable mobility • Urban planning • Bus stops • Public transport	Case study	described a planning development framework developed to foster urban sustainable mobility strategies for urban agglomerates of middle-sized cities.	Portugal

Table 1. *Cont.*

Author(s), Year, and Contributions	Explored Mobility Areas	Methodology Employed	Context	Countries
Næss et al. [55] researched the issues of sustainable mobility in urban planning and development based on evidence from Copenhagen, Denmark, and Oslo, Norway.	• Urban development • Decoupling • Sustainable mobility • Compact city • Planning discourse	Case study In-depth, semi-structured interviews	Studied and compared how decision-makers and planners are involved in the development of urban sustainability in cities towards formulating transport policies and land use in addressing sustainability challenges.	Denmark, Norway

Findings from Table 1 suggest that numerous research has been carried out to identify actions and investigate the individual factors, their influence, and interdependencies as related to sustainable mobility. But there are fewer studies that have examined specific factors to be considered in smart communities towards improving the adoption of eMobility-sharing services. Likewise, there are limited studies that have identified key factors that influence eMobility-sharing services policies for smart communities in European countries. Accordingly, this current study adds to the body of knowledge by exploring how smart communities can develop eMobility-sharing services.

2.7. Challenges of eMobility-Sharing in Smart Communities

This section mainly aims to address the second research question on how to improve individuals' adoption of eMobility-sharing solutions in smart communities. Presently, eMobility-sharing services are now increasingly using electric cars that are more environmentally friendly with lower to zero emissions to decrease overall climate impact. As such, EVs are becoming widely used in cities such as Stockholm, Oslo, and Oulu. eMobility-sharing services are influenced by a multitude of factors that are grounded on city characteristics, individual preferences, and country institutions [39]. Münzel et al. [39] also pointed out that the availability and use of different road transportation modes could influence the adoption of eMobility-sharing services. This is because if there is a reliable and operational public transit system within the city, the citizens may be nudged to travel daily without a car or multimodal travel mode, including eMobility-sharing. Opposing this, eMobility-sharing would be more useful in cities with a less operational public transit system since a car may be needed to supplement the mobility needs of residents. Another significant factor that influences eMobility-sharing is the population within a location, as this will largely impact the popularity and adoption across countries. eMobility-sharing is greatly influenced by available infrastructures as well as institutional strategies such as policies, regulations, and tax regimes [39].

Therefore, as in any transport initiative, policies need to be in place for eMobility-sharing to become a mainstream means of traveling within and across cities in the future. Although, electric cars often need higher direct investment and operating costs as compared to conventional combustion cars, which are typically associated with lower costs. But as electric cars occasionally do not have high purchase prices, there is a possibility that car-sharing services can increase usage and provision of electric cars globally to help citizens travel via vehicles powered by electricity. Another notable challenge identified in the literature relates to building up a trustful and effective collaboration between the actors across the extended enterprise involved in the eMobility-sharing service [5]. These include the enterprises responsible for ensuring efficient parking and charging of the electric mobility assets, battery capacity and charging station location management, easy reservation system, pricing scheme with payment based on time of use, etc., [5].

Similarly, the adoption of eMobility-sharing can be inspired by the presence of other sharing services within the city. This influence is seen as a spillover effect among innovations within the society as different sharing schemes can be complementary, for example, e-bike sharing and electric car-sharing [39]. In general, EVs present a new level of complexity to the transport system, as charging stations are needed for electric cars. Mostly during the daytime, there is a relatively low capacity of charging infrastructure available to support shared eMobility. This relative lack of flexibility and need for charging infrastructure can negatively impact the widespread of electric cars in the mobility-sharing economy as compared to the conventional combustion engine. For eMobility-sharing services to be able to sustain operations within smart communities, there is a need for well-developed charging infrastructures. But, on the contrary, evidence from the literature [9] suggested that the adoption of EVs for car-sharing services increases the usage of shared mobility services.

Furthermore, the adoption of digital technologies is an underlying trend that facilitates the adoption of eMobility-sharing to gain momentum, serving as a support in smart communities. Barriers in the transportation sector that impede innovation results from the lack of data sharing, standardization, and interoperability of interfaces to enable the required systems alignment, interaction, and integration needed for optimized eMobility-sharing services. This is because, at the core of the eMobility solution, data are needed to have a well-operational technical solution. Likewise, digital technologies are anticipated to play an essential role in the maturity of eMobility-sharing schemes to reach a state where multiple transport operators and transport service providers need to collaborate [41]. Data fusion, integrated multimodal information, journey planning applications, and ticketing platforms are some of the digital systems that need to be standardized and interoperable to enablers of eMobility-sharing.

Additionally, the increased penetration of handheld devices such as smartphones in society provides accessible eMobility-sharing services to a large cohort of users. Creating a smart mobility service attractive to users eMobility-sharing is dependent on real-time data to create well-integrated and functional systems for booking and payment will thus be central for eMobility-sharing eMobility-sharing. An early risk for many eMobility-sharing initiatives has been reduced market interest both for eMobility initiatives and underlying urban mobility suppliers [9]. Furthermore, the latest surge in demand and adoption of other eMobility assets, such as electric scooters within cities, has restructured the urban landscape and created new problems for urban policymakers. These micro-mobility services can perhaps create more transport options for citizens in the cities but also underlines the need for cooperation with municipalities to gain momentum. At the core of the eMobility model is a user-centric view, and high service experience will therefore be central. Likewise, as more service features and modal options are added, alignment between stakeholders will then be central, which can prove to be difficult as companies might need to share sensitive information [9]. There is also a possibility that strong incumbent mobility operators are unenthusiastic to engage in eMobility-sharing schemes as the required business model has not yet been widely established, and it is uncertain what the exact value might be.

2.8. Developed Model for the Adoption of eMobility-Sharing

This section provides evidence regarding the first research question on factors that influences individuals' adoption of eMobility-sharing solutions in smart communities. One approach to explore how eMobility-sharing services become embedded in society's everyday life is via a practice-based theoretical perspective. Practice-based theories have been employed for a wide range of societal needs, including energy, water, and food [5]. Examining not just eMobility-sharing practices but also the complexes or bundles in which eMobility-sharing are interwoven can, therefore, improve our understanding and broaden our knowledge of the systemic relations in which eMobility-sharing practices are embedded and thereby offer insights on how to design and implement eMobility-sharing in future sustainable mobility systems. This article applies the Diffusion of Innovation (DoI) theory as a practice theory to empirically examine eMobility-sharing in relation to the transport needs of citizens in smart communities.

DoI theory is employed in this study, analogous to prior studies [32,39]. The DoI theory was proposed by Everett Rogers in 1995 when the author described the diffusion procedure of innovation (e.g., a new service or product; here: eMobility-sharing) across the general population. According to DoI theory, the diffusion of innovation typically happens gradually, as some parts of the society will implement the innovation early on (i.e., innovators with about 2.5%, early adopters with 13.5%, and early majority with 34%), and other population will adopt the same technology such as eMobility-sharing services only when it has come to be the new norm (i.e., late majority adopters with about 34% and laggards with 16%) [56]. The characteristics among these adopters usually differ, and different strategies may be needed to foster the adoption of the innovation across different groups. The DoI theory also involves a final stage of the diffusion process, where the innovation has been completely adopted by society [57]. The theory further speculates that the user's adoption decision is motivated by a combination of individual characteristics (e.g., personality, socio-economic characteristics, or people's knowledge) in addition to five perceived characteristics of the innovation, resulting in either acceptance and adoption or non-acceptance and rejection of the innovation. The five perceived characteristics comprise perceived relative advantage (RA), perceived compatibility (CO), complexity (CX), trialability (TR), and observability (OB).

- The perceived relative advantage involves the benefits the innovation provides as compared to the existing service or product it intends to replace.
- Next, perceived compatibility measures the extent to which the innovation is more aligns or fits well with the users' needs, values, and characteristics.
- The perceived complexity of the innovation involves the ease of use of the innovation, measuring how easy the innovation is to understand and/or use.
- The trialability of the innovation assesses whether potential adopters have the opportunity to try, run, and test or experiment with the innovation prior to making the decision to fully adopt or not.
- Observability mainly comprises the degree to which the innovation delivers demonstrable or tangible results [39].

Based on the DoI theory, a research model is developed, as seen in Figure 3, to present the factors that influence individuals' adoption of eMobility-sharing in smart communities. The model suggests that users are more likely to adopt eMobility-sharing services early if they believe in the comparative advantage of eMobility solutions, its compatibility with their transportation needs, and its ease of use either using digital platforms or apps as facilitators. The adoption rate is further enhanced if the eMobility-sharing services can be assessed by citizens and also produces a visible positive impact on mobility needs. Overall, Rogers [56] maintained that (a) it is a wasted effort trying to convince laggards and late majority adopters to change, as they will hardly do (in any case in the short to medium term), (b) one should emphasize more on finding the early adopters and the innovators to find a mutual basis with them, and (c) the early majority of the innovation will convince the fence-sitters (i.e., those who are unsure or hesitant about accepting the innovation or not), and therefore, the early majority or first group of adopters is the demographics that will need the most attention. Based on these arguments, this study hypothesized the following:

H1. *The perceived characteristics of the eMobility-sharing solutions provided will significantly influence an individual's intention and use of eMobility innovation.*

H2. *The perceived characteristics of the eMobility-sharing solutions provided will significantly influence an individual's characteristics and perceptions towards eMobility innovation.*

H3. *The individual's characteristics will significantly influence the population in the society as regards to eMobility innovation.*

H4. *The adoption of eMobility-sharing solutions is significantly influenced by individuals who use the innovation in society.*

H5. *The adoption of eMobility-sharing solutions is significantly influenced by the individual characteristics of users in society.*

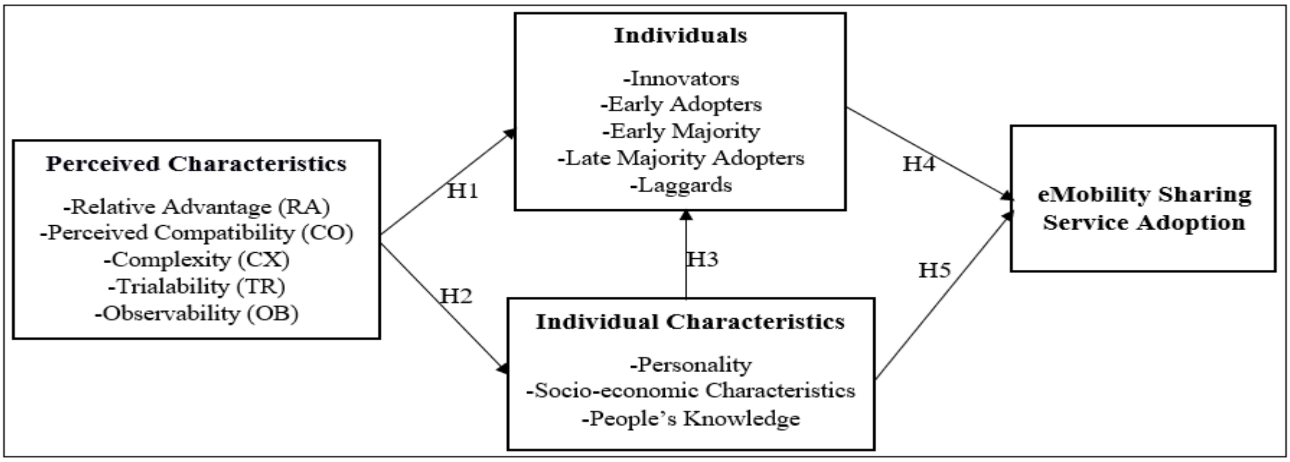

Figure 3. Developed research model.

Therefore, in this study, the factors that influence the uptake of eMobility-sharing solutions in smart communities are conceptualized and grounded on the DoI theory. Furthermore, the theory aids in distinguishing between prospective early (i.e., early majority, innovators, and early adopters) and late (i.e., laggards and late majority) adopters of eMobility-sharing solutions in relation to users' adoption intentions.

3. Methods

A mixed-mode method was employed, as recommended in the literature [47,48], to gain more understanding of eMobility-sharing services in smart communities. A mixed-mode method is employed in this research as it aids researchers in viewing respondents' or participants' perspectives, and it provides a medium to examine and verify that the research outcomes are justified based on the participants' experiences. Though, this method is criticized for being much more complex to implement as it entails knowledge to collect both quantitative and qualitative data. Furthermore, more time is necessitated to analyze and interpret collected data which may require more resources, such as time and finance [58,59]. But on the other hand, the mixed-mode method is specifically valuable in identifying differences between qualitative and quantitative results outcomes. Therefore, a mixed-mode method was employed in this study. Quantitative data were collected using survey questionnaires, whereas qualitative data were collected via interviews with participants that provide digital services in smart communities. The data were collected from selected cities in Norway and Ireland that deploy emerging technologies such as distributed ledger technologies (DLT), data mining, cloud services, digital twins, and cloud computing to digitalize smart services for citizens and businesses.

3.1. Quantitative Data Procedure

To empirically validate the developed model grounded on the DoI theory (see Figure 3), a survey questionnaire was conceptualized from prior studies targeting stakeholders and practitioners that provide digitalization services such as eMobility-sharing services in smart communities analogous to prior studies [24]. The questionnaire instrument was prepared in the English language. In developing the questionnaire instrument, potential attributes were identified from the literature. The quantitative data were collected mainly from 40 participants in 18 establishments based in Norway and Ireland involved in the +CityxChange smart city project (https://cityxchange.eu/ (assessed on 18 July 2023)). The questionnaire was delivered online in English between November 2020 till January 2021. The first section of the questionnaire specifies an introduction to the research study, and permission was collected from the participants. The second section involves collecting data as regards the demographic characteristics of the respondents (which includes the gender, age, enterprise type, services type provided, main role, years of experience, and familiarity with the developed approach) based on the ordinal scale. A purposive sampling technique was employed, targeting participants who had knowledge of digitalization services such as eMobility-sharing services in smart communities or were conversant with digital platforms adoption mainly in a smart community context. The survey attributes were measured based on a 5-point Likert scale which ranged from strongly disagree to strongly agree. The responses from the respondents provide data for verifying the developed model in Figure 3. The collected data were analyzed using statistical tools such as SPSS (Statistical Package for the Social Sciences) since this tool is suitable for quantitative analysis of complex data.

3.2. Qualitative Data Procedure

A qualitative research approach was carried out, and qualitative data were collected in this study, similar to a prior study [60]. The qualitative approach facilitates data to be collected across multiple different sources, such as from existing document reports, observations, and interviews [61]. Thus, qualitative data are collected to provide real-life applications of eMobility-sharing practices in smart communities. Accordingly, semi-structured interviews were carried out with different participants in two organizations based in Norway and Germany that provide digital services for eMobility-sharing in smart communities. To avoid biased responses from the qualitative study, purposively selected specialists were chosen to provide qualitative data as comments based on their knowledge of digital services for eMobility services. Semi-structured interviews were adopted as the data collection instrument since it is an extremely effective tool to thoroughly collect rich data that helps to identify the technical, business, and social aspects related to eMobility services sharing implementation in smart communities. The informants who provided data in both cases comprised a system developer, system architect, chief architect, mobile developer (from Norway), junior project manager, head of infrastructure development, senior technical analyst, and business development director (from Germany). Data were collected in Germany via an online interview conducted in November 2019 on how the organization implements micropayment to support eMobility services in smart communities. The qualitative data from Norway were collected from the period of 2019–2020 from the company that provides eMobility-sharing services and traffic management systems in smart communities. The interviews were performed face-to-face, online, and physically in the English language and were manually recorded by the interviewers from each of the enterprises for about 1 to 2 h, respectively.

4. Findings

4.1. Descriptive Statistical Analysis

Descriptive statistics aims to accurately describe the variables under study based on a detailed sample. Descriptive statistics is mostly determined based on the mean and standard deviations score of the studied model variables or individual attributes, as seen in the developed model in Figure 3. Descriptive statistics was used in prior studies that employed DoI theory to examine the distribution of the participant's response in relation to variables [32,39]; thus, this study also employs descriptive statistical analysis. The mean values of all variables or individual attributes should be greater than 2.5, and the standard deviation score should be closer to 1, indicating that the individual responses are close and not widely dispersed. Results from Table 2 suggest that the mean and standard deviation scores are within the necessary range. Next, the assessment of normality was checked by assessing the Skewness and Kurtosis scores, where the recommended cutoffs of 8.0 for Kurtosis and 3.0 for Skewness are adequate, as recommended in the literature [62].

Table 2. Descriptive statistics.

Variables	Attributes	Mean	Standard Deviation	Skewness	Kurtosis
Perceived Characteristics	Perceived relative advantage	3.6923	0.94733	0.037	−0.818
	Perceived compatibility	4.2308	0.83205	−0.498	−1.339
	Complexity	3.3846	0.65044	−0.572	−0.332
	Trialability	4.0769	0.64051	−0.053	0.061
	Observability	3.7692	0.83205	−0.528	0.519
Individuals	Innovators	3.3077	0.63043	−0.307	−0.317
	Early adopters	3.0000	1.08012	−1.876	4.784
	Early majority	3.3846	0.65044	−0.572	−0.332
	Late majority adopters	3.1538	1.14354	−1.929	4.441
	Laggards	3.1538	1.06819	−2.292	6.822
Individual Characteristics	Personality	3.5385	0.77625	−1.413	0.546
	Social economic characteristics	3.6923	0.85485	−1.187	1.143
	People's knowledge	3.6923	0.75107	0.611	−0.776
eMobility-sharing Service Adoption	eMobility-sharing1	2.9231	1.03775	−1.940	5.318
	eMobility-sharing2	3.0769	1.03775	−2.290	7.074
	eMobility-sharing3	3.4615	0.51887	0.175	−2.364
	eMobility-sharing4	3.3846	1.19293	−1.940	5.537
	eMobility-sharing5	3.9231	0.49355	−0.262	2.573

Results from Table 2 show the mean score based on the 5-point Likert Scale (1 to 5) response from the respondents. For mean value 1 = least important, 2 = fairly important, 3 = important, 4 = very important, and 5 = most important. Results from Table 2 suggest that all attributes' mean scores are higher than 3.0000, which weighs the significant measures of the respondents' perception of each variable concerning the diffusion of eMobility services sharing. Also, Table 2 implies that the attributes' standard deviation values do not deviate from the value of 1, highlighting that the respondents' responses are largely similar. Table 2 also shows that the Kurtosis and Skewness values are between the set benchmark (lesser than 8.00 for Kurtosis and also lesser than 3.00 for Skewness).

4.2. Exploratory Statistical Analysis

Exploratory statistical analysis was carried out on the quantitative data in relation to the developed model to assess how statistically significant are the questionnaire attributes. Furthermore, exploratory statistical analysis helps to determine to what extent the questionnaire attributes influence the respondents' viewpoint towards eMobility-sharing services in smart communities. The exploratory statistical analysis helps to assess the reliability and validity of the data. Reliability assesses the internal consistency of the questionnaire attributes related to each variable in the developed research model measured by testing Cronbach's alpha α. Hence, Cronbach's α coefficient must be greater than or equal to 0.7, as recommended by [63–65]. Moreover, in exploratory statistical analysis evaluation of the correlation, factor loadings of the attributes, Bartlett's test of Sphericity (p-value), and Kaiser–Meyer–Olkin (KMO) test of sampling adequacy approximate Chi-Square $\chi 2$ were tested as suggested by [24,56] to assess the reliability of the developed research model attributes. KMO scores between 0.5 are just adequate; KMO score is categorized as average (0.5–0.7), adequate (0.7–0.8), better (0.8–0.9), and excellent (above 0.9).

Results from Table 3 indicate that Cronbach's α coefficient is within the required benchmark of 0.7. Next, validity was assessed based on the correlation coefficient or Pearson correlation coefficient (r) [62]. As recommended by Cohen et al. [66], the correlation coefficient range is categorized as "0.1 to 0.29", representing a weak coefficient, "0.30 to 0.49", denoting an average coefficient, and "0.50 to 1.0", signifying a strong coefficient. Likewise, the Pearson correlation coefficient should be between −1 to +1. Results from Table 3 suggest that the Pearson correlation coefficient for the independent variables (perceived characteristics, individuals, and individual characteristics in relation to the dependent variable, which is "eMobility-sharing service adoption"), ranges from −0.056, 0.595, up to 0.173. This suggests a very weak, good, and weak correlation of the independent variables with the dependent variable (eMobility-sharing service adoption). These results confirm that the data are valid for hypothesis testing. Although, the correlation is weak mainly due to the limited sample size of the survey data employed in this study.

Table 3. Statistical test of reliability and validity.

Variables	Attributes	Factor Loading	Cronbach's Alpha (α)	Pearson Correlation Coefficient (r)
Perceived Characteristics	Perceived relative advantage	0.711	0.810	−0.056
	Perceived compatibility	0.821	0.785	
	Complexity	0.960	0.790	
	Trialability	0.847	0.788	
	Observability	0.868	0.788	
Individuals	Innovators	0.828	0.765	0.595 *
	Early adopters	0.894	0.773	
	Early majority	0.752	0.783	
	Late majority adopters	0.955	0.770	
	Laggards	0.979	0.781	
Individual Characteristics	Personality	0.932	0.767	0.173
	Social economic characteristics	0.811	0.771	
	People's knowledge	0.942	0.801	
eMobility-sharing service Adoption	eMobility-sharing1	0.914	0.772	1.000
	eMobility-sharing2	0.950	0.799	
	eMobility-sharing3	0.784	0.778	
	eMobility-sharing4	0.968	0.794	
	eMobility-sharing5	0.797	0.783	

* Correlation is significant at the 0.05 level (2-tailed).

Likewise, results from Table 4 show the KMO and Barlett's test scores resulting from the factor analysis test carried out in SPSS, showing that the KMO values of 0.506 are within the 0.5 limits, showing that the attributes are marginally valid at a significance of 0.0262. Additionally, Bartlett's test of sphericity was given as $\chi 2$ (7.685), at $p < 0.000$, indicating that the attributes are reliable to advance with hypotheses testing of the developed model.

Table 4. KMO and Bartlett's Test.

Kaiser–Meyer–Olkin Measure of Sampling Adequacy.		0.506
Bartlett's Test of Sphericity	Approx. Chi-Square $\chi 2$	7.685
	df	6
	Sig.	0.0262

4.3. Hypotheses Testing of the Developed Research Model

The developed research models' hypotheses are validated using regression statistical analysis in SPSS. Regression analysis is used in this study to test the hypotheses because it is flexible and versatile in uncovering quantitative dependency among model variables [67].

For the regression test, the path coefficient (β), R^2, effect size measure (t-value), and *p*-significant value were used to reject or confirm a hypothesis, as presented in Table 5. Results from Table 5 show the hypotheses testing using regression analysis. The relationship strength of the variables is measured by checking the R^2 value of the variables. The results imply that perceived characteristics influence individuals' use of eMobility-sharing services adoption at R^2 = 0.010 (1.00%) of the variance, which shows very low influence. The results indicate that perceived characteristics influence individual characteristics in the use of eMobility-sharing services adoption in smart communities at R^2 = 0.221 (22.1%) of the variance. Next is the individual characteristics' influence on individuals' intention to use eMobility-sharing services with R^2 = 0.037, interpreted at 3.7% of the variance. This is followed by individual influence on eMobility-sharing services adoption with $R^2 = 0.354$ interpreting at 35.4% of the variance. Lastly, the impact of individual characteristics towards the use of eMobility-sharing services adoption has an $R^2 = 0.030$ interpreting at 3.00% of the variance.

Table 5. Hypotheses testing.

Relationships	Regression Analysis					
Hypothesis Path	**Hypotheses**	**Path Coefficients (β)**	**R Square (R^2)**	**t-Value**	***p*-Value (Sig.)**	**Decision**
Perceived Characteristics → Individuals	H1	−0.101	0.010	2.469	0.031	Confirm
Perceived Characteristics → Individual Characteristics	H2	0.470	0.221	1.767	0.105	Reject
Individual Characteristics → Individuals	H3	0.193	0.037	3.600	0.004	Confirm
Individuals → eMobility-sharing service Adoption	H4	0.595	0.354	3.089	0.010	Confirm
Individual Characteristics → eMobility-sharing service Adoption	H5	0.173	0.030	2.944	0.013	Confirm

Decision: Hypothesis is valid if t-value ≥ 1.96 and p-value ≤ 0.05.

Furthermore, all the model attributes have a direct path coefficient as revealed by the beta result (β = −0.101, 0.470, 0.193, 0.595, and 0.173), which signifies the relative significance of the variables (see Table 5), apart from H1 with a value −0.101. Moreover, by assessing the t-test value of all factors, the results suggest that the values are greater than 1.96 [67], benchmark (2.469 (H1), 3.600 (H3), 3.089 (H4), and 2.944 (H5)), for H1, H3, H4, and H5 as recommended by Hair et al. [64]. However, 1.767 (H2) is below the suggested benchmark. The result indicates that the model hypotheses H1 and H3–H5 are significantly supported, and H2 is not supported based on the qualitative data employed in this study. Further, considering the p-value is smaller than the significance level $p = 0.05$ for all hypothesized paths (0.031, 0.004, 0.010, and 0.013), the hypotheses (H1 and H3–H5) are thus confirmed but H2 is rejected with a p-value of 0.105.

These results suggest that H3 has the highest t-value with 3.600 with a p-value of 0.004 which states that individual characteristics influence individuals in using eMobility-sharing services. Also, the results reveal that H2 has the lowest t-value with 1.767 with a p-value of 0.105, suggesting that perceived characteristics (perceived relative advantage, perceived compatibility, complexity, trialability, and observability) of users do not necessarily influence the individual characteristics (personality, social, economic characteristics, and people's knowledge) towards the use of eMobility-sharing services.

4.4. Findings from Qualitative Data

This section provides the data from the semi-structured interviews that were carried out with different participants in two organizations based in Norway and Germany that provide digital services for eMobility-sharing in smart communities, as discussed in Section 3.2. The collected data are presented in an ArchiMate Modelling language (archimatetool.com (assessed on 16 July 2023)) to show the real-life implementation of the eMobility-sharing service in smart communities. The ArchiMate Modelling language was used in this study as it offers an intelligible tool that can be adapted to different stakeholders' requirements. ArchiMate language is different from other modelling tools as it does not facilitate automated reasoning. It offers concepts, objects, and relationships that are appropriate mainly for modeling enterprise digitalization. As compared to prior eMobility studies ArchiMate is employed in this study for modeling current and future urban operations as it provides concepts for designing a real-life business and societal model that fits businesses, applications, infrastructures, and technologies. Therefore, based on the collected data, an eMobility service ArchiMate is employed to model the qualitative data, as seen in Figure 4.

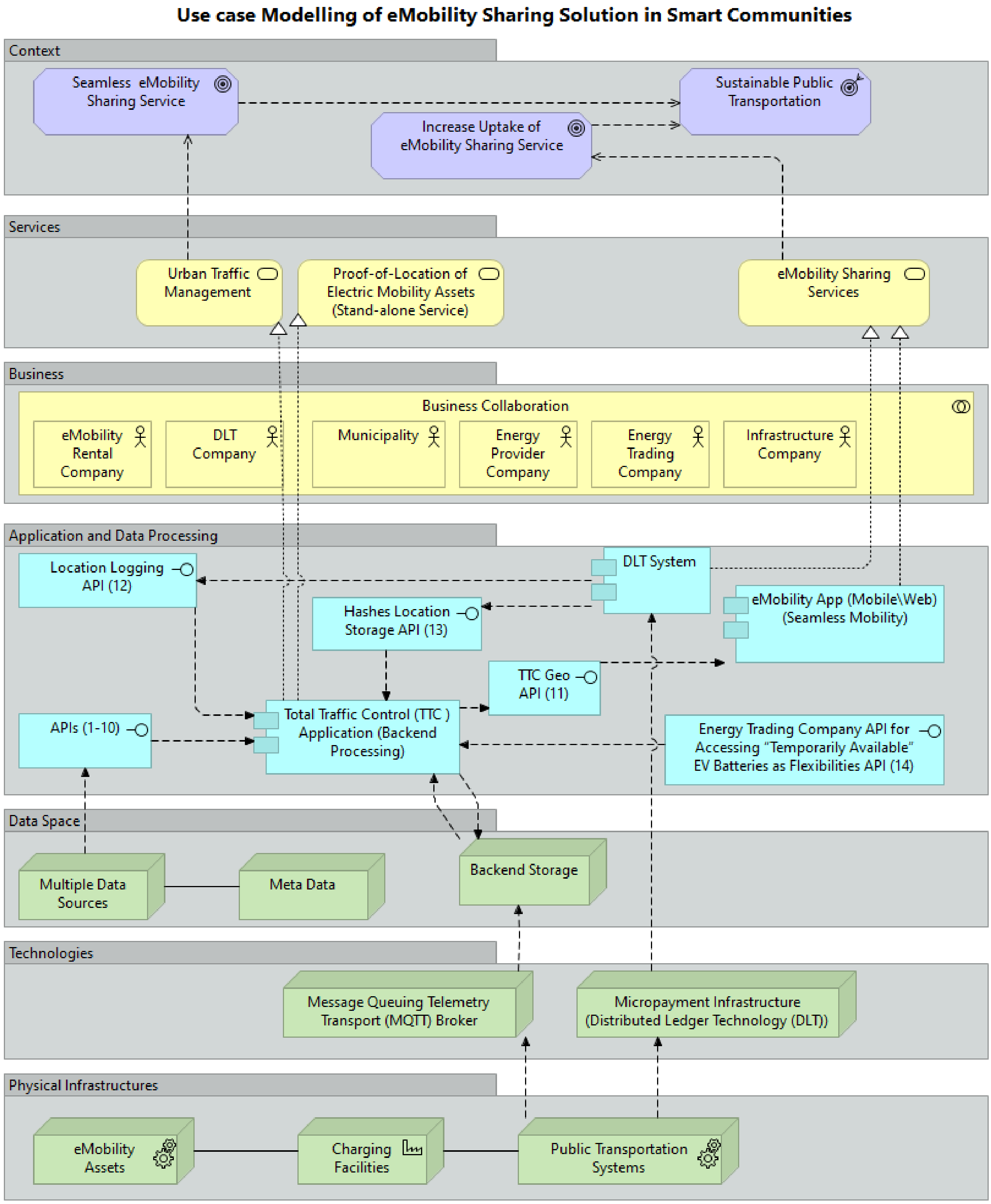

Figure 4. Use case modeling of eMobility-sharing solution in ArchiMate.

The eMobility system sharing solution is developed as part of the Task in the +CityxChange smart city project (https://cityxchange.eu/ (assessed on 16 July 2023)). It includes a backend system named Total Traffic Control (TTC), developed by the infrastructure company in Norway and supported by the DLT company in Germany, which retrieves, stores, and provides transport data (mainly in Trondheim, Norway). The TTC backend collects data from various data providers via APIs, as seen in Figure 5, and makes it available in a normalized and standardized format via a TTC API to the end-user eMobility App (Mobile/Web).

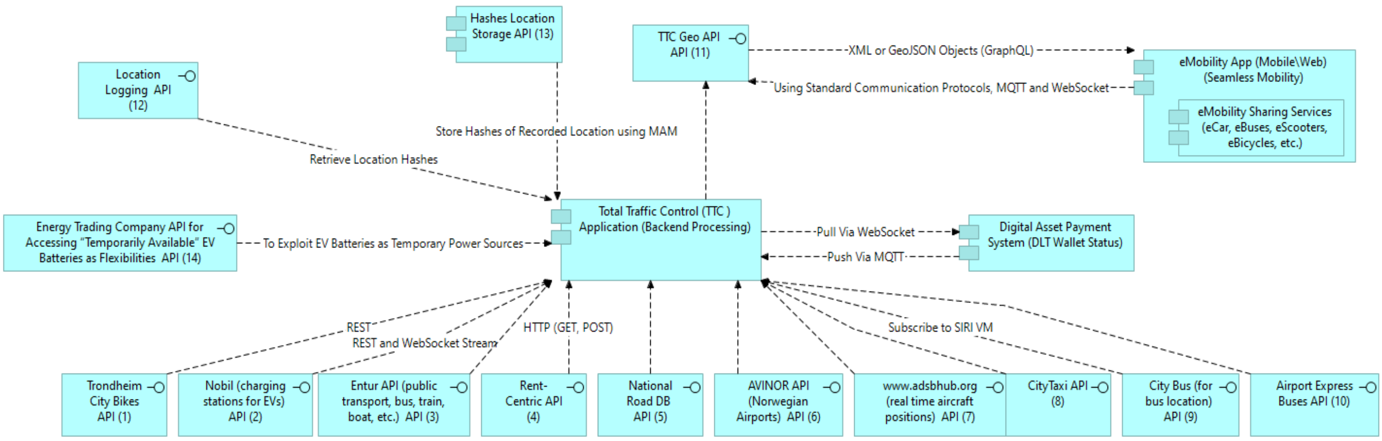

Figure 5. Application and data processing for eMobility-sharing services.

The end-user eMobility App connects to the TTC backend and retrieves and displays the eMobility options that are available for the user near a selected position on the map. Furthermore, a digital asset payment system was developed by DLT in Germany, which aids end users in booking and paying for a multi-modal journey offered by different public transportation providers seamlessly in one step. Also, the TTC backend integrates with the energy trading company for accessing "temporarily available" EV batteries as flexibilities via an API are provided by the energy trading company (as seen in Figure 4) for use in Positive Energy Building and Districts PEBs/PEDs, which provides information into available energy data to support the exploitation of EV batteries as temporary energy sources during peak hours for grid balancing.

Figure 4 demonstrates the use case modeling of eMobility-sharing services in ArchiMate, which comprises the physical infrastructure, technologies, data space, application and data processing, business, services, and context layers. The details of each layer have been discussed in prior studies [7,20,27,29], where the layers have already been discussed in detail. The physical infrastructure layer comprises the eMobility assets, charging facilities, and public transportation systems available in the city to be used by citizens to meet their mobility needs. Next, the technologies layer captures the cloud-based technologies deployed to support eMobility-sharing services such as Message Queuing Telemetry Transport (MQTT) Broker and the Micropayment Infrastructure (Distributed Ledger Technology (DLT)), which supports the operation of the entire infrastructure.

The data space layer comprises multiple data sources such as real-time, open, historical, other data sources, metadata, and backend storage used by the companies to optimize eMobility-sharing services. The application and data processing layer comprises digital platforms and systems that provide access to data. Then the business layer shows the main enterprises that collaborates to provide the eMobility-sharing services to the community, as seen in Figure 4. Finally, the services layer shows all mobility-related services provided, and the context layers capture the end users, municipality, businesses, and government needs and requirements, such as sustainable public transportation.

Further, several Application Programming Interfaces (APIs), as seen in Figures 4 and 5 (API 1–10), have been employed by the two organizations based in Norway and Germany to support eMobility-sharing services.

Table 6 and Figure 5 depict the application and data processing layer in Figure 4 for eMobility-sharing services in smart communities. Figure 5 further presents how the APIs works and also provides technical specification of the APIs employed to provide eMobility-sharing services to all stakeholders illustrated in Figure 5 as well as end users (commuters).

Figure 5 suggests that many data sources are used by the eMobility application backend to provide seamless eMobility services in smart communities. As seen in Figure 5, the application and data processing layer comprise different APIs that provide data to the Total Traffic Control (TTC) application (backend processing). A description of the APIs is shown in Table 6.

Table 6. Description of the APIs in the eMobility-sharing solution use case.

API #	API Name	API Owner	API Consumer	API Description
1	Trondheim City Bikes	City bikes	TTC application	Uses REST APIs to provide information about the stations where the bikes are parked.
2	Nobil (charging stations for EVs)	Nobobil	TTC application	Uses REST APIs to provide national registry of charging stations for Electric Vehicles (EVs).
3	Entur (public transport, bus, train, boat, etc.)	Entur data	TTC application	Provides access to the national registry for all things involving public transport, bus, train, boat, etc.
4	Rent-Centric	Car-sharing data (eMobility Rental Company)	TTC application	Is a mobility solution provider that offers information about parking and EVs location.
5	National Road Database	Road datex	TTC application	Provides roadside signs and taxi ranking.
6	AVINOR (Norwegian Airports)	Flight info.	TTC application	Handles and owns most Norwegian airports and provides flight information.
7	Adbshub.org (real-time aircraft positions)	Third-party data	TTC application	Provides a community-driven service that provides real-time aircraft positions.
8	City taxi	City taxi company	TTC application	Provides information on taxi positions.
9	City Bus (for bus location)	City Bus DB	TTC application	Provides information on good, updated, accurate, and correct bus positions.
10	Airport Express Buses	Third-Party Data	TTC application	Provides information on real-time positions of Værnes-ekspressen airport express buses.
11	TTC Geo API	Infrastructure company	eMobility application	Uses REST APIs to provide information from TTC application.
12	Location Logging	DLT company	TTC application	Provides data that logs the location of the traveler.
13	Hashes Location Storage	DLT company	TTC application	Stores the location data of the traveler.
14	Accessing "Temporarily Available" EV Batteries as Flexibilities	Energy Trading Company	TTC application	Provides data that simulates temporarily available EV batteries as flexibilities.

5. Discussion and Implications of the Study

5.1. Discussion

Innovation theories in the literature, such as DoI theory, stress the role of niches that inventions can nurture without influence from incumbent competitors and rules [39]. To understand the individuals' behaviors and uptake of eMobility-sharing service in smart communities, this study examines individuals' intention and use of the eMobility-sharing service innovation grounded on the DoI theory. Prior studies in the literature related to eMobility explored the effective analysis of micro-EV via a framework and establishment study in demonstration projects by employing various analysis methods [68]. As seen in Figure 3, this study identifies various factors to investigate individuals' perception of eMobility-sharing service based on the individual characteristics, perceived characteristics, and individuals' adoption stage impact towards the overall adoption of eMobility-sharing service adoption in smart communities. Findings from this study identify issues that impact individuals' adoption of eMobility-sharing services related to the overall demographics of potential adopters, which limits the general user base. This also involves the socioeconomic state of individuals who will accept to pay for the use of the provided eMobility-sharing services [69]. This observation is in line with findings from Rogers [56], where the author highlighted how individual adoption of a particular innovation is aggregated into diffusion models of innovations. Generally, early adopters of new systems or technological innovations are mostly characterized by age (younger age groups), education (higher education), and income (higher income).

Similarly, Christensen et al. [5] added that since ICT-based solutions drive mobility as a service, this might increase the risk of technological exclusion for people having difficulties with using digital technologies, possibly due to social demographic factors such as age, education, etc. This finding is analogous to results from Petersson [9], where the author reported that changing societal attitude to eMobility-sharing is another underlying factor that affects the transport sector in European countries such as Sweden in general; the younger population taking driver's licenses is decreasing. As the younger age group particularly, millennials have surfaced as a group with less dependent on the usage and ownership of privately-owned cars. Instead, they are more inclined to try new transport modes resulting in a societal shift with respect to transportation. At the same time, the previous generations were more dependent on the use of personal cars. This result is consistent with findings from Karl [36], where the author stated that young generations no longer consider owning a car as a status symbol for quality of life. Still, environmental protection and sustainability are of great importance to these demographics in society.

Findings from the literature suggested that the current city's legacy of spatial urban planning particularly will impact the adoption of innovations such as eMobility-sharing services. This is because the urban form, which involves physical buildings with different structures and densities alongside other structural elements, defines transportation planning, especially for micro-eMobility assets such as e-bicycles and e-scooters. Therefore, the landscape and size of a city influence the adoption of transport innovations within the city. Similarly, dense historic cities, where car usage and parking may be challenging, draw citizens to various mobility modes as compared to large outspread, or dispersed modern cities, where distances are obvious and car usage is more feasible [39]. In dense municipalities, it is likely that shared mobility is easily reached and accessed; as such, it will be frequently used. To this end, the density of a city is moreover important for a cost-effective operation of eMobility-sharing services for extended enterprises such as technical backend providers (IT Infrastructure), payment solutions, ticketing solutions, dynamic multiservice journey planners, ICT infrastructure, and insurance companies [70,71], involved in the provision of environmentally friendly transportation.

5.2. Implications for Theory and Practice

Evidence from this study reveals that eMobility-sharing is topical and will continue to be, particularly regarding adoption issues. Further contributions from this study to the literature related to the fact that this is one of the fewer studies that have explored the adoption of eMobility-sharing services grounded on innovation theories such as DoI theory. This is the key finding, as this will be useful to different actors, particularly those outside the research community who have a minimal understanding of eMobility-sharing services. This will foster efficient cooperation towards a clear path for eMobility across smart communities. Findings from this study aim to develop deeper insight into challenges mitigating the uptake and adoption of eMobility-sharing services. These findings are expected to increase policymakers' understanding of what barriers are faced by individuals adopting EV-sharing services. This will provide more knowledge of how smart communities can transit to more sustainable modes of transport. Also, this study contributes by providing a deeper understanding of business sharing schemes perspective in theory and how eMobility-sharing can be deployed in practice within smart communities. The findings provide implications on the contribution of eMobility-sharing services on the electrification of cars and further, examine how these trends can co-develop smarter communities of the future.

Smart communities of the future require sustainable mobility solutions for clean transportation due to increasing urbanization. To reduce environmental and social impacts and congestion, efficient solutions such as eMobility-sharing are necessary to limit reliance on private vehicle ownership. Due to the increased adoption of eMobility across different countries, there is a need to examine the impact of eMobility-sharing on the transport system to obtain more knowledge on the barriers relevant to future eMobility solutions [9]. This study explores the potential for leveraging eMobility-sharing services to reduce the need for citizens' dependency on private car usage toward a mobility model shift for sustainable transportation in smart communities. Implications from this study, as advocated by Corazza et al. [18], stated that eMobility maturity is based on the willingness of mobility transport operators 'to share data and be open; existing legislations, policies, and regulations; residents' willingness and familiarity with eMaaS sharing solutions; availability and accessibility of digital technologies and readiness of the transport infrastructure and services within the city.

Moreover, findings from Petersson [9] stated that eMobility adoption is influenced by legal, economic, societal, and informative factors. The legal factor comprises rules and regulations enabling eMobility on a formal level. The economical involves taxes and charges, the societal ranges from physical planning and parking rules, and lastly, the informative ranges from creating a common understanding and knowledge about benefits to society. Petersson [9] added that to improve these mobility-sharing services, the cultural and social challenges for emerging niches, issues associated with charging and parking cost, and policy barriers related to the judicial and economic levels need to be addressed. Furthermore, general knowledge relating to the potential of eMobility-sharing services is low among citizens. As such, more understanding is needed of the role of these sharing services [72]. As societal change and adoption of innovation is typically a slow process, there is a need to efficiently communicate the value of eMobility-sharing services. Also, small economic margins, which, for example, provide economic incentives and lower Value Added Tax (VAT) for individuals, may influence individuals' adoption of innovations such as eMobility.

5.3. Implications for Transport Policy

Findings from this study provide insight into the role of eMobility-sharing services and the factors that affect individuals' adoption of these electric mobility-sharing services grounded on DoI theory. Evidence from the literature showed that current mobility schemes are anchored in an understanding of the daily mobility needs of individuals based on informed, rational, and choice-making decisions. This study proposes providing door-to-door-based multi-modal and inter-modal transport choices that offer users efficient, comfortable, convenient, and sustainable shared eMobility services. The findings aim to promote the uptake of eMobility-sharing services as an alternative to personal car use by considering temporal contingencies of everyday life such as personality, knowledge, and socioeconomic state of individuals. As the mobility model shifts from car-based ownership to electric car-sharing, access comes with some positive implications, such as convenience; maintenance costs; freedom from the use of a private car; and less time needed to find parking spaces, especially within the city center (as electric car-sharing scheme usually has dedicated parking spaces).

Presently, most policies in European countries are aimed at making private car use less attractive based on road pricing and physical limitations due to land-use planning for car traffic and parking. This results in limited space for automobility and private car ownership in cities, as pointed out by Christensen et al. [5]. Further findings from this study provide a new structural discussion on factors that can be improved that could help address the challenges impeding the acceptance, uptake, and adoption of eMobility-sharing services identified from the literature. Where the physical layout of the cities [73], involving available parking space for personal cars, are key contributors to the mobility model shift from ownership to shared mobility uptake. This is in line with the findings from the literature, which states that the shift to more sustainable mobility strategies, such as the provision of less resource-intensive transport modes, necessitates not only that environmental-friendly alternatives are made available but also that existing unsustainable substitutes are limited by, for example, limiting the space for private car and automobility in cities [5].

Findings from this study may be useful for transport planners, the research community, and policymakers presenting a conceptualized state-of-the-art related to the eMobility-sharing concept. In addition, this study suggests that mobility service operators, municipalities, and policymakers should invest in fast-charging infrastructure near residential areas and shopping centers, as mentioned in the literature [68]. Similarly, the standardization of fast-charging infrastructure significantly enhances EV market share and performance. Shortening the charging time through fast charging has the potential to increase the adoption of EVs by citizens. Also, providing a charging infrastructure around regularly traveled locations such as the city center will positively impact the citizens' uptake of electric car-sharing [68,74]. Therefore, municipalities deploying fast-charging infrastructure near locations such as shopping centers, where micro eMobility assets such as e-scooter or e-bicycles sharing services are being used, will possibly improve the welfare of citizens and aid the transition towards green modal shift.

6. Conclusions

Smart communities are typically municipalities that employ innovative technologies and new urban infrastructures to improve the quality of services and quality of life of inhabitants. The emergent prominence of electric mobility sharing services is changing the transportation behavior of individuals within smart communities. This study contributes to the body of knowledge by improving our understanding of the factors that influence individuals' perception towards the adoption of eMobility-sharing services based on DoI theory. This is one of the first studies to develop a model grounded on DoI to investigate the adoption of eMobility-sharing services in the literature.

Data were collected using survey questionnaires from participants involved in a smart city project +CityxChange in Norway and Ireland to validate the developed research model (Figure 3). Findings from the regression test in SPSS suggest that H3 has the highest impact, which states that individual characteristics influence the population in using eMobility-sharing services. Also, the results reveal that H2 has the lowest influence and is not supported by the data suggesting that perceived characteristics (perceived relative advantage, perceived compatibility, complexity, trialability, and observability) of users do not necessarily influence the individual characteristics (personality, social, and economic characteristics and people's knowledge) towards the use of eMobility-sharing services. Overall, HI, H4, and H5 were confirmed to be valid, suggesting that perceived characteristics influence individuals' use of eMobility-sharing services (H1). This is followed by individual influence on eMobility-sharing services adoption (H4) and, lastly, the impact of individual characteristics towards the use of eMobility-sharing services adoption.

Additionally, qualitative data via interview were collected from participants in Norway and Germany, and the findings were modeled in ArchiMate modeling language to demonstrate how eMobility-sharing services are implemented in real life as a use case study within smart communities, as seen in Figure 4. Furthermore, the findings present the APIs employed to provide eMobility services to citizens in a smart community in Norway. To the knowledge of the author, research on eMobility-sharing services is still in the early stages. Innovations from this article explore the research area of eMobility in smart communities targeting actual users in the society based on individual characteristics of users in the society, perceived characteristics of the eMobility-sharing solutions provided, and different types of individuals in the society as regards the innovation (eMobility-sharing service). Therefore, findings from this study can contribute to widening the knowledge of the plausible factors to improve on to increase the uptake and adoption of eMobility-sharing service in smart communities. Yet, a limitation of this study is that the sample size of the study is small. In the future, more data will be collected from eMobility users and providers to further assess the adoption of eMobility-sharing services in smart communities.

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