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Big Data Driven Multi-Tier Architecture for Electric Mobility as a Service in Smart Cities: A Design Science Approach

Bokolo Anthony Jnr.*[1]., Sobah Abbas Petersen[2], Dirk Ahlers[3], John Krogstie[4]

Department of Computer Science, Norwegian University of Science and Technology, NTNU, NO-7491 Trondheim, Norway[1, 2, 4]
Department of Architecture and Planning, Norwegian University of Science and Technology, NTNU, NO-7491 Trondheim, Norway [3]

Abstract

Purpose

Electric Mobility as a Service (eMaaS) is suggested as a possible solution to ease transportation and lessen environmental issues by providing a collaborative transport sharing infrastructure that is based on Electric Vehicles (EVs) such as electric cars, electric bicycles, etc. Accordingly, this study proposes a multi-tier architecture to support the collection, processing, analytics, and usage of mobility data in providing eMaaS within smart cities. The architecture employs Application Programming Interfaces (APIs) to enable interoperability between different infrastructures required for eMaaS and allow multiple partners to exchange and share data for making decision regarding electric mobility services.

Design/methodology/approach

Design science methodology based on case study by interview was employed to collect data from an infrastructure company in Norway to verify the applicability of the proposed multi-tier architecture.

Findings

Findings suggest that the architecture offers an approach for collecting, aggregating, processing, and provisioning of data originating from sources to improve electric mobility in smart cities. More importantly, findings from this study provides guidance for municipalities and policymakers in improving electric mobility services. Moreover, our findings provide a practical data-driven mobility use case that can be utilized by transport companies in deploying eMaaS in smart cities.

Research limitations/implications

Data was collected from a single company in Norway, hence it is required to further verify the architecture with data collected from other companies.

Practical implications

eMaaS operates on heterogenous data which are generated from EVs and used by citizens and stakeholders such as city administration, municipality transport providers, charging station providers, etc. Therefore, the proposed architecture enables sharing and usage of generated data as openly available data to be used in creating value-added services to improve citizens quality of life and viability of businesses.

Social implications

This study proposes the deployment of electric mobility to address increased usage of vehicle which contributes to pollution of the environment that has serious effect to citizens quality of life.

Originality/value

This study proposes a multi-tier architecture that stores, processes, analyze and provides data and related services to improve electric mobility within smart cities. The multi-tier architecture aims to support and increase eMaaS operation of EVs towards improving transportation services for city transport operators and citizens for sustainable transport and mobility system.

* Corresponding author. E-mail address: anthony.j.bokolo@ntnu.no

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1. Introduction

With constant increase in urban residents, the need to plan and deploy smart services for better transportation management is becoming more evident (van der Steen *et al*., 2015: Jnr *et al*., 2018). Thus, mobility is becoming a prominent research field in smart city domain. Mobility is an important factor, that affects citizens' well-being and quality of life (Abdelkafi *et al*., 2013). These mobility services are motivated by innovations in Information Communication Technology (ICT) implemented to mitigate environmental issues, improve social inclusion, and enhance economic growth (Dijk, *et al*., 2013). Hence, innovations such as electric mobility is deployed to improve transportation in cities, where electric mobility involves a system of technologies, infrastructures, and actors interacting to achieve a sustainable transportation via use of electricity (Abdelkafi *et al*., 2013; Hinz *et al.,* 2015). Over the years implementation of electric mobility paved way for Mobility as a Service (MaaS) that aims to connect private and public transport operators in a city, intercity and across national level, and envisages to integrate current applications and services (such as scheduling, booking, access to real time data, and ticket payment) required by citizens for mobility (Kamargianni and Matyas, 2017).

In smart cities MaaS involves citizens` sharing and purchase of mobility services (e.g. bus, car, bike, taxi, rail share) owned by transport service providers (Anthony Jnr *et al*., 2019). This service is supported by payment platforms and applications aggregation integrated with real time, online, and historical processing of 'Big Data' that support mobility service demand (Badii *et al*., 2017). Correspondingly, MaaS collects data from citizens and provides information in real-time to improve mobility service performance (Docherty, *et al*., 2015). Similarly, eMaaS involves the electrification of vehicle fleet consuming battery power, plug-in hybrid and/or other Green renewable energy sources making Electric Vehicles (EVs) emission free hence achieving sustainable mobility, increasing electricity storage, and more importantly decarbonization the transportation sector (Lieven, 2015).

Presently, existing approaches do not adequately address the effective collection, processing, and storage of electric-mobility data (Docherty *et al*., 2015; Zabasta *et al*., 2018). They are mostly concerned with improving mobility data and not considering data management of EVs in relation to the environment (Melis *et al*., 2016). Furthermore, mobility services are faced with issues relates to silos which hinders smart services due to lack of interoperability and openness to produce value-added services across multiple platforms. Therefore, there is need for interoperable approach to foster development of open ecosystems and expose the commercial potential of mobility data (Cheng *et al*., 2015), where interoperability refers to the ability of different devices to communicate with each other and exchange information.

Moreover, processing and visualizing of mobility related data is not effective due to data being generated from different infrastructures dealing with heterogeneity of devices and communication protocols, as well as different mobility service interoperability (Krylovskiy *et al.,* 2015). Such challenge involves integration of innovative ICT solutions to process data from EVs that can be used by applications to improve e-mobility services such as Application

Programming Interface (API) capable of facilitating interoperability and providing access to processed and stored data required to provide appropriate information on mobility services in cities (Kamargianni and Matyas, 2017). Thus, API serves as data adapters integrated for establishing connections to different mobility platforms, external databases, and real-time streaming data. In addition, researchers such as Sánchez *et al.* (2013) suggested developing architecture to address requirements for the actualization of smart services. The authors mentioned that architecture supports the deployment of applications that access heterogeneous data produced from different sources in an open and standardized approach. Accordingly, this study aims to address the following research question:

- How to facilitate the acquisition, processing, analysis, retaining, and provisioning of mobility relevant data originating from several sources, such as position of EVs, routing, EV usage, charging stations, EV parking stations, battery charge condition of EVs, and public transport data.

In this regard, this study adds to the body of knowledge by proposing a multi-tier architecture that deploys APIs to offers an approach for processing and provisioning of mobility relevant data originating from several sources, such as position of EVs, routing, EV usage, charging stations, EV parking stations, battery charge condition of EVs, and public transport data, etc. This paper provides practical evidence for energy sector management that can be utilized by mobility service providers and city administrators when deploying big data driven mobility service platforms in smart cities. Also, the proposed architecture offers a scalable, flexible processing of real time, online, and historical mobility data as suggested by Cheng *et al*. (2015). The rest of the paper is organized as follow. Section 2 elaborates on literature review. Section 3 is the proposed architecture. The research methodology is presented in section 4. The findings are given in section 5. Discussion and implications are presented in section 6. Finally, the conclusion of the paper is outlined in section 7.

2. Literature Review

This section provides a review on background of electric mobility as a service, big data for eMaaS in smart cities, API for eMaaS in smart cities, related works, and theoretical background.

2.1. Background of Electric Mobility as a Service

The debate on sustainability and global warming is of importance in European countries and across the world and transportation sector is challenged with reducing CO_2 emissions (Anthony *et al.*, 2019). This is because traditional combustion engine vehicles contribute to pollution of air quality, whereas EVs are characterized as being lowly polluting, energy efficient, and noiseless (Brandt *et al.,* 2012). Hence, transition towards electric mobility is believed to enhance energy security, create trade balance by lessening oil import as well as facilitating the consumption of renewable energy by utilizing batteries of EVs as energy storages (Mäkelä and Pirhonen, 2011; Spickermann *et al*., 2014).

During the last decades research and development related to eMaaS have been extensively discussed in areas linked to optimization, interconnectivity, and integration of smart and seamless transport services for sustainability (Dijk *et al*., 2013). Presently, there are studies published that explored mobility services related to vehicle-sharing and on-demand transport solutions which are not integrated with public transport system and as such operate in silo (Cheng *et al*., 2015). The drive towards eMaaS envisions to enable an interconnected and co-operative transport eco-system that provides citizens with comfortable mobility service. Accordingly, the eMaaS eco-system consists of several actors, technologies, and infrastructures as seen in Figure 1.

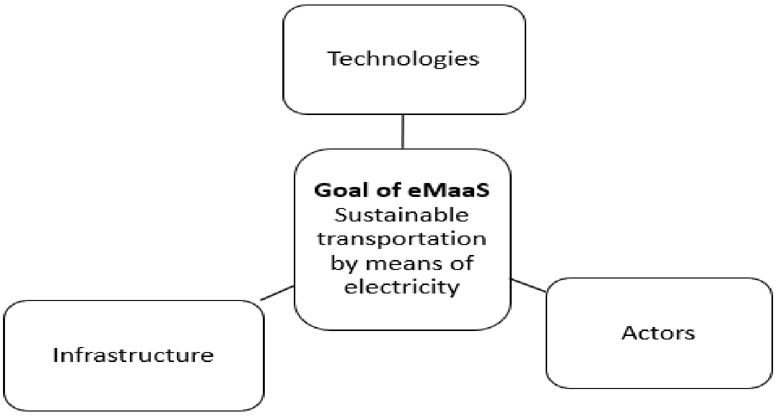

Figure 1. eMaaS components adapted from Abdelkafi *et al.* (2013)

The actors, technologies, and infrastructures in Figure 1 comprises of transport operators or mobility service providers, data providers for routing, platform and technology providers or technical backend providers, ICT infrastructure, insurance companies, regulatory bodies, research and universities institutions (Abdelkafi *et al*., 2013). Similarly, eMaaS utilizes different types of data which includes public data (routes, quality of roads, schedules, etc.), business data (ticket information, charging stations, fees, etc.), and private data (profiles, targets preferences, etc.) for EV reservation and availability, management of citizens data, and other related mobility data in creating value-added services as seen in Figure 2.

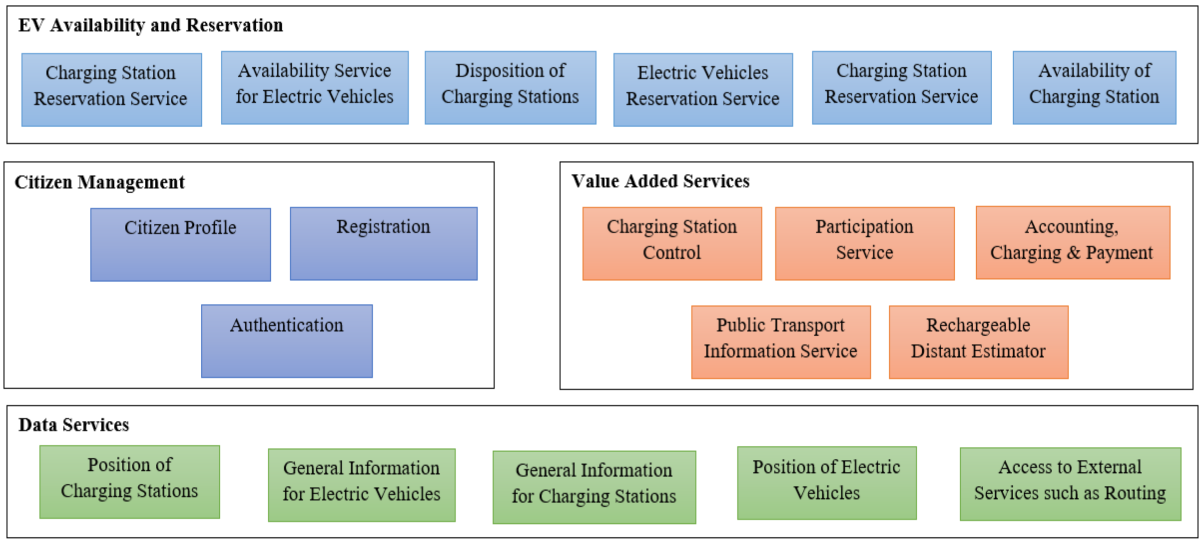

Figure 2. Overview of eMaaS adapted from (Tcholtchev *et al.,* 2014)

Furthermore, eMaaS has the potential to reduce dependence on private vehicles and provide seamless mobility as it allows the collaboration and integration across transport operators, by providing seamless transport services to citizens via a single application (Benevolo *et al*., 2014; Ahuja and Khosla, 2019). eMaaS provide data for citizens to have open access to reliable, easy, viable, flexible, and seamless transit from one destination to another within urban and intercity trips (Tcholtchev *et al.,* 2014).

2.2. Big Data for eMaaS in Smart Cities

Presently, huge volume of data is collected from eMaaS characterized with variety and high velocity which forms "Big Data". In mobility sector these generated data sets are large enough, usually dynamic, unstructured, in different varieties, thus difficult for traditional database infrastructures to store, manage, and process such data (Badii *et al.,* 2017). This result to the increasing need for efficient and practical big data analytics tools to process the data by converting, analyzing, and utilizing the data towards realizing beneficial information to improve mobility services (Al-Jaroodi and Mohamed, 2018; Borozan *et al*., 2018). Similarly, data from transport companies, public administrations and municipalities can be coarsely gathered as open data which are data which that can be utilized freely by anyone (Badii *et al.,* 2017).

The collected data comprises of historical, real time, and online data (Barbosa *et al.,* 2016). Where, historical includes data with low degree of concurrency and in file formats such as Comma-separated values (CSV), Text File format (TXT), JavaScript Object Notation (JSON), Extensible Markup Language (XML) (Ramachandran *et al.,* 2018). Real-time and online includes scheduled data which entails periodic readings from pervasive systems such as from eMaaS application data with high degree of concurrency and velocity representing and streaming data from the web (posts, blog, tweets, etc.) or from EV meters, smart sensor, and other smartphones, weather stations, geolocation enabled devices, etc. (Costa and Santos, 2016; Witt *et al.,* 2018). Therefore, big data techniques can boost the dynamic of eMaaS by exploiting and extracting valuable information from transport data from different sources that may provide long-term sustainability for the creation or optimization of electric mobility (e-mobility) services.

2.3. API for eMaaS in Smart Cities

Application Programming Interface (API) are developed software programs that facilitates communication between systems (Borgogno and Colangelo, 2019). APIs provides access and links to specific datasets, databases, and web getaways and are currently utilized by enterprises such as Google, Microsoft and Apple in creating data sharing platforms. The aggregation of mobility related data collected from several domains is not feasible without a common approach, since data are generated by different enterprises related to eMaaS in different formats and different standards (Badii *et al.,* 2017). Thus, the datasets are mostly not interoperable since each data has been produced by different systems, people, and time, etc. Moreover, each data has different ownership license where they can be open, commercial or private (Choi *et* *al*., 2013). Therefore, aggregated mobility data both open and private can be exploited via APIs for enabling e-mobility solutions in delivering value added services to citizens such as identification of available EV services, locations, providing recommendation on routes (Badii *et al*., 2017).

Thus, APIs in smart city allow eMaaS to develop and offers opportunities to transport service providers to take advantage of emerging trends and convergence of e-mobility and big data. APIs are different from traditional web services since they emphases on simplicity in providing the needs of modern applications leveraging on internet technologies (for example, Hypertext Transfer Protocol (HTTP), Representational State Transfer (REST), and JSON) for scalability in breaking the barriers of locked data silos (Holley *et al*., 2014). Moreover, APIs create technical gateways for achieving a data-driven economy and have been acknowledged as a key enabler of interoperability of services in smart cities (Badii *et al*., 2017). In eMaaS scenario API aids citizens to publish and/or subscribe to e-mobility related services (Choi *et al*., 2013). API provide free access to mobility data to offer services to citizens and businesses in creating open ecosystem of mobility data sources, mobility data providers, and mobility application and/or service developers in making transport predictions, detecting anomalies in EV fleets for early warning and for producing recommendations to eMaaS operators (Tcholtchev *et al*., 2014). Furthermore, APIs are means to extending eMaaS capabilities to citizens, stakeholders, etc. to facilitate the usage and exploiting of collected fragmented, unstructured, and heterogeneous data to improve e-mobility services via open interfaces, deployed on Internet standards such as JSON and XML for data exchange (Holley *et al*., 2014).

2.4. Related Works

Currently, there are a few studies that explored API and big data application for eMaaS in smart cities, but they focused exclusively on improving mobility services. Among these studies Ruohomaa and Salminen (2019) conducted research on MaaS in smart cities and proposed a new method for smart mobility. The authors focused on investigating the possibilities and issues related to electric city bike services and how produced data could be employed to improve mobility services as innovation. An electric bicycle digital ecosystem was developed that comprise of inhabitants, bicycle supplier, universities, companies, and city planning as components. In addition, Badii *et al*. (2017) applied APIs to develop a knowledge based smart city architecture to provide wide range of data and process to support mobility services. The architecture mainly comprises of data streams, city operator, data/service operator, big data aggregation & processing, APIs, decision making tools, development tools, and city user tools. The proposed solution used static, real time, open, and private data to facilitate transport services with the aim of achieving sustainable mobility system.

Furthermore, Kamargianni and Matyas (2017) designed a business ecosystem for MaaS that depicts the actors involved in mobility service aimed at offering a holistic method for improving MaaS practice and further highlighted the areas to be researched towards improving materialization of mobility in smart cities. Also, Melis *et al.* (2016) designed a service-based architecture for smart mobility via crowdsensing. The researchers illustrated the application of microservice paradigm to deploy mobility services platform and developed applications as orchestration of available elements to leverage the prospect of data sharing between different system in a controlled environment. The architecture comprises of data management algorithms and access control policies, orchestration, and authentication, QoS, business intelligence, federation agreements. Besides, Kuehl *et al*. (2015) proposed a service-based business framework for e-mobility. The authors aimed to develop mobility services in achieving a complete ecosystem. Their study focused to foster the adoption of e-mobility mainly depends on the provision of complete service ecosystems to improve citizen's experience.

Another study by Tcholtchev *et al.* (2014) proposed a mobility data cloud and implemented a prototype to validate the approach. The researchers also presented a mobility data architecture that integrated APIs and REST services for acquisition, analysis, aggregation, and use of mobility data produced from sources such as EV charging stations, petrol stations, position of vehicles, battery condition of EV, etc. to support the collaborative shared use of mobility services. Additionally, Abdelkafi *et al.* (2013) developed an innovative business model for electric mobility based on a value-focused framework that comprises of value creation, value proposition, value capture, value delivery, and value communication to support the classification of mobility patterns useful for electric mobility. Similarly, Tcholtchev *et al.* (2012) examined the association of network providers and cloud services, towards handling open data for e-mobility services in smart cities. The authors designed an architecture for distributed data cloud and established how networks service is linked to electric mobility cloud services with the aim of providing an effective streaming of data.

Likewise, Mäkelä and Pirhonen (2011) developed a business model utilized as a tool to improve value creation of e-mobility as a compound private service system. The authors aimed to employ business approach towards understanding and defining complexity of developing e-mobility and value creation. Moreover, Beaume and Midler (2009) proposed an innovative design strategy for EVs to reinvent eco-mobility by presenting a theoretical framework to facilitate innovation management of mobility innovation. The framework comprises of innovative design theory, usage driven design, value driven strategies, and co-innovation partnerships.

Findings from the review of the studies indicates that several efforts have been put forward towards eMaaS, but most of the studies focus on improving business models for mobility services based on historical and real time data (Tcholtchev *et al*., 2014; Badii *et al.,* 2017). But issues related to addressing interoperability of data produced by different devices required for eMaaS has not been completely addressed in the literature. In eMaaS, interoperability plays an important role in providing data transfer and communication among EVs deployed on communication protocols. Besides, in resolving silos that prevents mobility services due to lack of openness and interoperability to produce new added value across several platforms. Evidently, interoperable approach is required to foster development of open data ecosystems, to unlock the commercial potential of big data (Kubler *et al*., 2017) in providing an approach to expose and access e-mobility data in a secure and efficient way (Schleicher *et al*., 2017). Accordingly, API can be deployed as data adapters which can be used for establishing connections to CSV, external databases, files, spreadsheets, Global Positioning System (GPS) data, and real-time mobility data (Chaturvedi and Kolbe, 2018). Therefore, there is need for an architecture that integrates APIs that can deal with interoperability of data collected during eMaaS operation in smart cities.

2.5. Theoretical Background

This sub-section provides an overview of theories that can be adopted in eMaaS domain. Based on the literature the socio-technical systems theory, actor network theory, and layer architecture of digital technology are reviewed to provide insight on how human and technical actors in electric mobility systems share information and coordinate their actions.

2.5.1. Socio-Technical Systems Theory

The Socio-technical Systems (STS) theory was proposed from open systems theory and it referred to as a paradigm that consists of a design process, a conceptual scheme, a set of values about work, a methodology, contextual conditions such as inter-dependence with the environment (Manz and Stewart, 1997). STS is based on past tradition grounded on workplace, sociology, and psychology research. Also, STS is referred to as a comprehensive model of the dimensions of technical and social systems. It is based on the premises that a work unit or an organization is a combination of technical and social constituent in its environment. Hence, the technical and social elements must work together to achieve tasks, in producing physical and social outcomes. STS approach also connects with the work structure and its environment (Appelbaum, 1997; Baxter and Sommerville, 2011). It comprises of boundary management, which is a procedure of protecting the work system from external factors and enabling the exchange of necessary information.

2.5.2. Actor Network Theory (ANT)

Actor Network Theory (ANT) was established in the 1980s from research of Bruno Latour, John Law and Michel Callon in order to examine the relationship between human and non-human objects within a scenario (Alcadipani and Hassard, 2010). The ANT method was developed within the domain of sociological studies of science and technology, grounded on French semiotics and philosophy. ANT highlights the nature of theorizes and relations that they can be both material and semiotic. ANT is perceived as a socio-philosophical method that aims to investigate complex social settings by considering relational variables referred to as associations. Researchers (Whittle and Spicer, 2008; Seuwou *et al.,* 2017) maintained that in ANT the "social is not directly linked to the society rather it is aligned with types of connectors. Furthermore, ANT enables the description of a set of actors (referred to as the network) that determines, or influence an action, which supports the identification of correlations between and within actors in different or the same networks. It includes four main components (actor, links, network, and action) (Bruni and Teli, 2007).

2.5.3. The Layer Architecture of Digital Technology

The layer architecture of digital technology was developed by Yoo *et al.* (2010) to pave way for layered architecture in providing connection between device and service and between contents and network of homogenous data. As showed in Figure 3, the layered architecture comprises of four layers (devices, networks, services, and content).

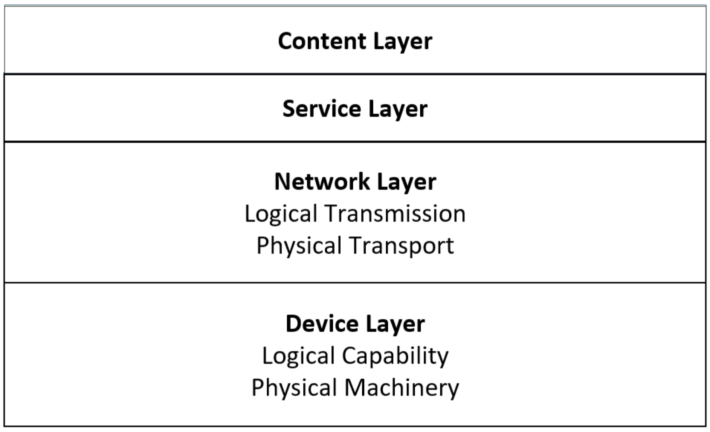

Figure 3. The layer architecture of digital technology adopted from (Yoo *et al.,* 2010)

Next, Figure 4 establish a clear link between socio-technical systems theory, actor network theory, and the layer architecture of digital technology in conceptualizing the multi-tier architecture.

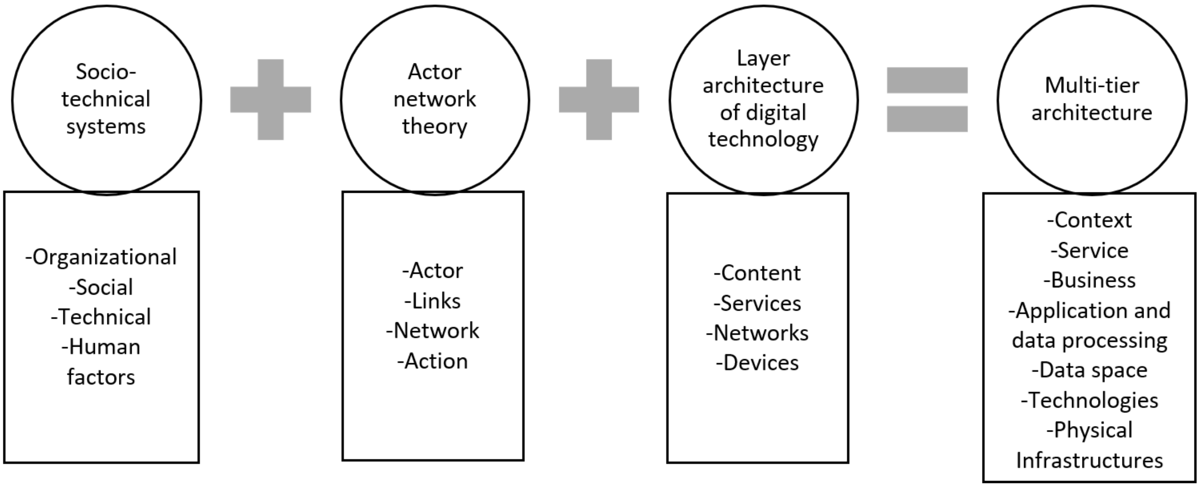

Figure 4 Link establishment between prior theories and the proposed architecture

Figure 4 illustrates the conceptualization of the reviewed theories to develop the multi-tier architecture layers. Respectively, STS theory aims to propose systems that comprises of organizational, social, technical, and human factors required in deploying real world systems such as electric mobility in smart cities. STS theory intended to ensure that the organizational and technical areas of a system effectively works together (Majchrzak and Borys, 2001). Furthermore, it intends to better understand how human, organizational, and social factors influence the ways work is accomplished and how technical systems are utilized. This understanding can help contribute to design technical systems, business processes, and organizational structures (Baxter and Sommerville, 2011). The underlying principle of STS is that systems such as e-mobility operations should be a process that considers both technical and social factors that influence the functionality and usage of EVs to improve transportation in municipalities. In relations to the e-mobility case STS theory aims to employ socio-technical approaches to design seamless mobility services that can reduce risks that mobility systems may face.

Additionally, for ANT the actor or the actant, is referred to as main object and rather involves the relationship of various factors, that integrates to form an actor-network (Alcadipani and Hassard, 2010). Thus, in relation to e-mobility in smart cities an actor may be an individual (citizen), a group (energy company), transport company, municipality administrator, an idea (electric mobility), a piece of software (mobility application used by citizens) to achieve seamless e-mobility, a material object (electric vehicle), etc. that acts towards something (achieving eMaaS). It may not certainly be the cause of an action but alternately may change and improve the state of activities by making a substantial difference (Seuwou *et al*., 2017). The second factor is the links or relationships which occur between the actors and may consist of information or resource exchange sent to subscribers (citizens) within the networks. The third factor network may be an idea, an individual, a physical object, a group, or inanimate object. It may also be a collaborative assembly of group or entities, or sequence of actions as well as a number of possible mediators. Lastly, the fourth element is the action itself which relates to activity or considering what needs or wants of the actors either human or non-human (Whittle and Spicer, 2008).

In the layer architecture of digital technology (see Figure 3), device layer comprises of a logical capability layer (operating system) and physical machinery layer (computer hardware). The logical capability layer mostly provides control and management of physical devices and connects physical systems to other layers (Yoo *et al.,* 2010). Likewise, the network layer comprises of a logical transmission layer (network standards such as TCP (Transmission Control Protocol)/Internet Protocol (IP) or peer-to-peer protocols) and a physical transport layer (radio spectrum, physical cables, transmitters, etc.). Next, is the service layer which involves applications that directly support citizens and stakeholders to create, update, retain, and use content (Yoo *et al.,* 2010). Lastly, the contents layer comprises of data sources such as texts, images, sounds, and videos that are saved and shared. The contents layer also offers directory information and metadata regarding the data origin, content, copyright, ownership, etc. The proposed four layers characterize different design hierarchies, and each layer relies on the other layer to function based on a set of standards and protocols employed to deploy e-mobility services (Yoo *et al.,* 2010).

Furthermore, socio-technical systems and actor network theory can provide theoretical background of actors and process involved to achieve e-mobility operations. Conversely, the layer architecture of digital technology explored the need for content, service, network, and device layers to support the deployment of digital services such as eMaaS. However, socio-technical systems and actor network theory did not explored the role of data types. Also, the layer architecture of digital technology did not address interoperability of data via a middleware. Although, the architecture proposed by Yoo *et al.* (2010) is concerned about history and online data as seen in the content layer. The integration of history, real-time, online data produced utilized to facilitate services such as e-mobility was not explored. Thus, there is need to propose the architecture that considers both history, online data as well as real-time data as well as interoperability of big data.

3. Design and Development (Proposed Architecture)

This section presents the proposed multi-tier architecture based on previous theories (see section 2.5) incorporated based on the first to third steps of design science methodology (see Figure 6) for artefact development to facilitate processing, analyzing and storage of collected data related to eMaaS within smart cities. The architecture integrates APIs to enable interoperability between different infrastructures required for eMaaS and aids multiple partners to exchange and share data for making decision regarding e-mobility services. Accordingly, Figure 5 depicts the proposed multi-tier architecture which comprises of seven layers.

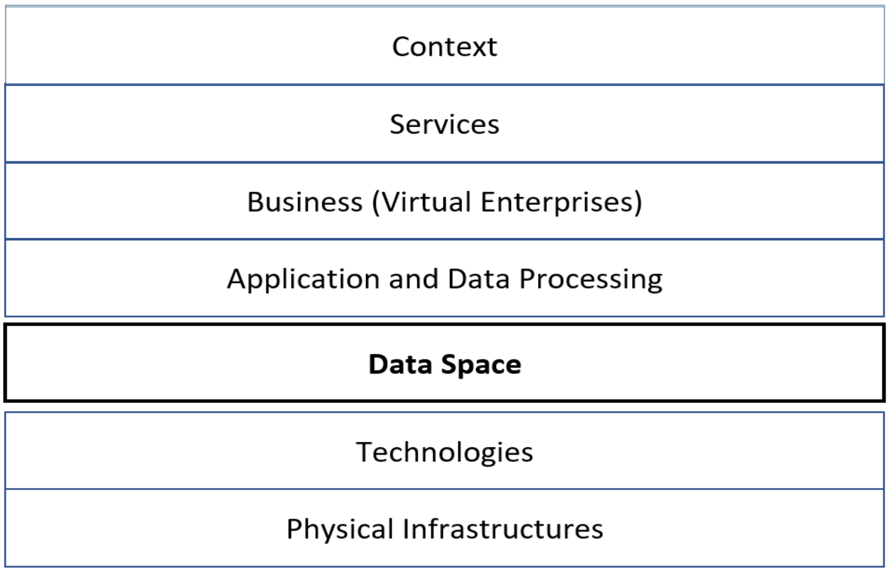

Figure 5. Proposed multi-tier architecture

Figure 5 presents the proposed multi-tier architecture (to accomplish the third phase of design science methodology (design and development)), which comprises of context, service, business, application, data space, technology, and physical infrastructures layers. Thus, each of the layers are discussed below;

3.1. Context Layer

The context layer is concerned with the main feature or capability to be provided which in the context of the study is eMaaS to citizens (Abu-Matar and Davies, 2017). Moreover, the context layer captures the needs and requirements of all stakeholders involved in eMaaS. It also involves the main target to be attained which is the increase of eMaaS operations to reduce pollution and ease of transportation of citizens. Hence, this layer depends on all other layers in the architecture to be actionable.

3.2. Service Layer

Services layer refers to operations required to accomplish eMaaS business processes (Barbosa *et al*., 2016). This layer involves all individual services that works together in ensuring that the mobility services are provided to citizens and stakeholders (Moreno *et al*., 2016). The service layer is an important layer in the architecture because it provides a communication module between municipalities, transport companies, and other partner that offers e-mobility related services (Abdelkafi *et al*., 2013). In addition, service layer aids trusted third party mobility data providers such as routing location, weather service providers, etc. to add new services or update existing services to create a mobility value-chain of services to citizens and stakeholders (Tcholtchev *et al*., 2014).

3.3. Business Layer

This layer entails enterprises that collaborates virtually to create eMaaS to citizens in smart cities. Thus, business layer involves businesses' strategies employed by each enterprise to meet their goals as relates to sustainable transportation (Ruohomaa and Salminen, 2016). This is achieved when the virtual enterprises align their business approach with IT thus creating a medium for IT to facilitate mobility operations from a managerial perspective by modelling the collaboration of each enterprise across boundaries (Bokolo and Petersen, 2019). Hence, this layer provides the governance and operational capabilities needed to deploy eMaaS in smart cities (Mäkelä and Pirhonen, 2011).

3.4. Application and Data Processing Layer

The application and data processing involve the software programs and APIs employed to provide eMaaS solutions to citizens. Thus, this layer integrates APIs to process, provide, and manage mobility related data from various sources to ensure that transport services are provided to citizens (Brundu *et al*., 2016). This is achieved by the deployed APIs integrated to address interoperability issues for managing mobility operation (Costa and Santos, 2016). Additionally, the application layer facilitates citizens to use trusted mobility software to request and get response via APIs that push and pull transport information to citizens (Bellini *et al*., 2018). Hence, this layer provides systems that exposing smart city mobility services to support the actualization of a sustainable transportation operations. Similarly, applications layer provides mobility information utilized by municipalities to make policies to manage transportation demand and improve flow of citizens in smart cities (Badii *et al*., 2017). Also, this layer utilizes data from data space layer to execute contextual analysis for decision-making. Furthermore, this layer facilitates developers to utilize existing APIs to implement new applications for e-mobility services in providing contextual transportation information to citizens via eMaaS applications (Melis *et al.,* 2016).

3.5. Data Space Layer

This layer is the center of the architecture as it comprises of types and sources of data required to facilitate eMaaS operations in smart cities (Pradha *et al*., 2018). The data space layer describes how the mobility related data repository are organized and accessed (Otto *et al*., 2017), and specifies where meta-data, such as transport routing description information are stored and how they can be accessed (Ramachandran *et al.,* 2008). Besides, this layer deploys a variety of data manipulation, organization, and storage to maintain data continuum (Silva *et al.*, 2018). Moreover, data space layer comprises of relational and non-relational databases such as MySQL, Mongo, Maria, Couch database that creates an open data eco-system repository of historical, online and real time streaming data to support eMaaS operations that are accessed via APIs that offers opportunities for open web services via open and linked data from various sources (Tcholtchev *et al*., 2012). Furthermore, this layer provides access to historical mobility data in different format such as XML, CSV, and JSON that can be used to generate valuable insights to improve transport operations (Badii *et al*., 2017).

3.6. Technologies Layer

This layer describes the software and hardware infrastructure that supports the deployment of eMaaS operations in smart cities (Tcholtchev *et al*., 2014). The technology layer comprises of the essential computing, telecommunications networks, and physical hardware (Melis *et al*., 2018). This layer provides technical elements that align the physical infrastructure and defines how the infrastructure related to the services, application and data processing, and how data layers are linked (Bellini *et al*., 2018). Additionally, this layer involves the management of hardware devices such as EV card readers, sensors, Radio-frequency Identification (RFID) chips, data processing tools, etc. utilized to efficiently process and analyze e-mobility related data generated from physical devices, by supporting the processing of plethora of heterogenous variety of data produced by EVs and other eMaaS applications (Barbosa *et al*., 2016). Furthermore, this layer provides mechanisms to proficiently process, transform and analyze large sets of streaming real-time data (Silva *et al*., 2018).

3.7. Physical Infrastructures Layer

This layer includes the generation of real time mobility data from EVs, charging stations, buses, taxi, bikes and other physical devices related to transportation services in smart cities (Silva *et al.,* 2018). This layer produces massive real-time data collected in aggregate from physical sources that is transferred to the technology layer for big data processing, analysis, and storage (Al-Jaroodi and Mohamed, 2018). These produced data include unstructured or semi-structured data streams with high degree of velocity and variety that comprises of JSON, CSV, XML, TXT File format, etc. (Cheng *et al*., 2016). Furthermore, this layer employs communication protocols such as Bluetooth, Zigbee, Near Field Communication (NFC), Machine-to-machine (M2M), Zwave, Radio Frequency Identification (RFID) sensors, actuators, and global positioning system (GPS) terminals, wi-fi or Bluetooth that provide comparatively short-range communication coverage among EVs (Krylovskiy *et al*., 2015).

4. Research Methodology

This study adopts design science (DS) methodology by employing case study approach. Design science research is a problem solving paradigm that has its origins in engineering and sciences as a problem solving paradigm (Ilevbare *et al*., 2016). It aims to provide answers to design problems by creating innovations that describe the technical capabilities, ideas, products, and practices through which the design, analysis, management, implementation, and use of

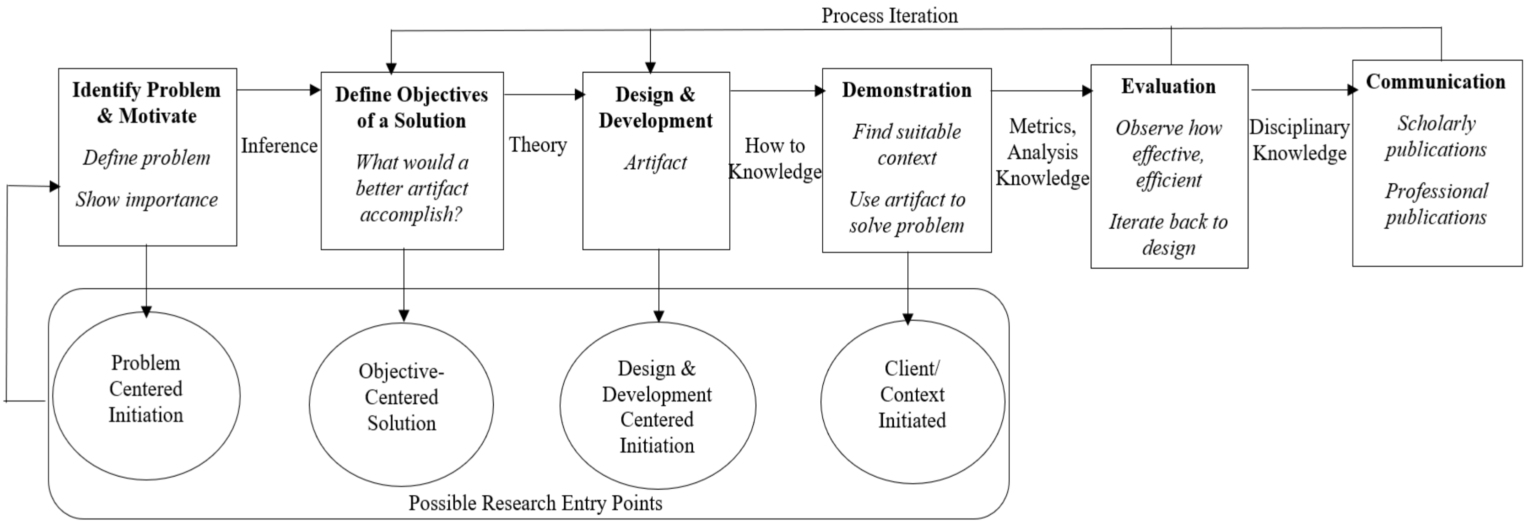

Figure 6 Design science research methodology adapted from Peffers *et al.* (2007)

Figure 6 depicts design science methodology each of the process are described below;

4.1. Problem Identification and Motivation

This initial phase aims to specify and define the research problem to be addressed intended to show the importance of the current research. Respectively, where this study aims to address interoperability between different infrastructures required for eMaaS to facilitate exchange and sharing of data for making decision regarding e-mobility services.

4.2. Defining the Objectives for a Solution

The purpose of this second phase is to specify the objectives for the solution to be defined; which includes a definition of how the proposed multi-tier architecture can deploy APIs to resolve the problems presented in the previous phase. The required resources entail knowledge of problems state and current solutions as specified in section 3, where previous theories (socio-technical systems theory, actor network theory, and the multi-layered model) are incorporated to conceptualize the proposed multi-tier architecture (see Figure 4).

4.3. Design and Development

This phase comprises the design and development of the proposed multi-tier architecture, describing how the architecture support the collection, processing, analytics, and usage of mobility data in providing eMaaS within smart cities. This phase is show in Figure 5 and specified from section 3.1 to 3.7.

4.4. Demonstration and Evaluation

The demonstration phase is combined with the evaluation phases in this current research as a single phase. Thus, in this phase, the proposed multi-tier architecture is presented to validated by means of case study by interview in order to assess the applicability of the architecture. The evaluation phase is specified in section 4.6 and 4.7, where demonstration and findings from the evaluation is presented in section 5 of this paper.

4.5. Communication

The final phase involves the reporting, documenting, and publishing of the case study findings from this current research to enable scalability and replications in other cities to improve current e-mobility services as seen in section 5. Besides, findings from the case study is to be published in a reputable scholarly journal (international journal of energy sector management).

Furthermore, since the architecture can either be practically replicated or demonstrated case study approach is employed as recommended by Yin (2004), where data was collected using interview from an infrastructure service provider in Norway to practically verify the proposed multi-tier architecture. Additionally, the evaluation (using case study) of the developed artifact (the proposed multi-tier architecture) provides feedback and evaluates how much the artifact resolves the problem, so that it is possible to enhance both the artifact and the method of designing it.

4.6. Case Study Protocol

Case study protocol was employed to avoid bias and incorrect interpretation in the data collection. This research philosophy is interpretive, and confirmatory approach aimed at verifying the multi-tier architecture. Case study by interviews was used for data collection that comprises of semi-structured questions which focused on participants' knowledge on e-mobility operations Accordingly, the interview protocol is shown in Figure 7.

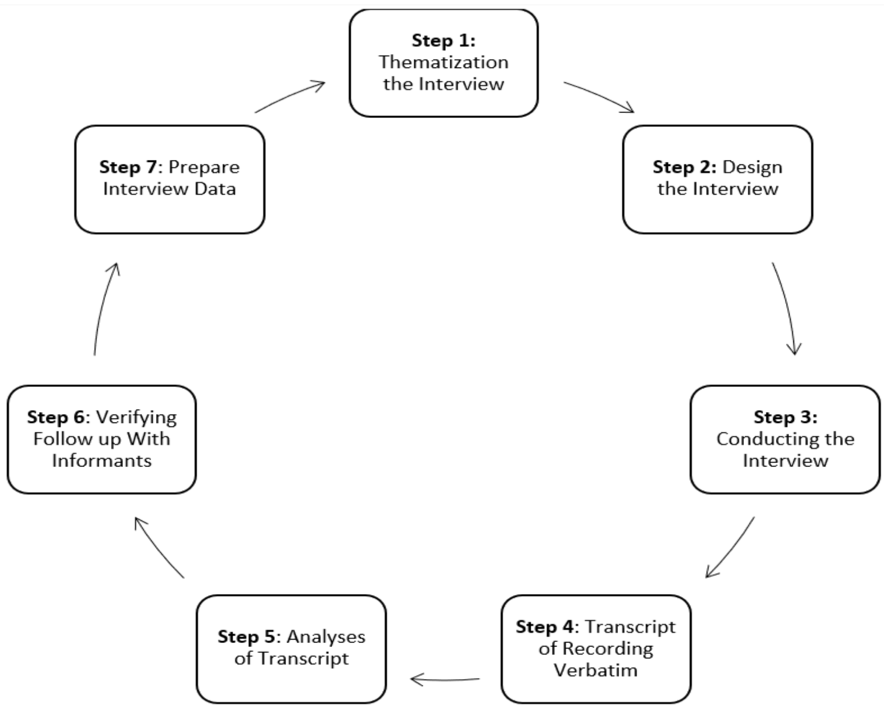

Figure 7 Interview procedure for this study

Figure 7 depicts the interview protocol employed for data collecting and analyses from the participants as suggested by Anthony Jr (2018) each phase was followed in this study.

Respectively, the first phase involves thematization of the interview by formulating the aim of the interview which is to verify the multi-tier architecture. Interview was employed to collect data as it aims to provide practical insight on informant's perception (Junior *et al*., 2018; Jnr *et al.*, 2019), on electric-mobility and big data in smart city and how the presented architecture can be employed to improve transport services in municipalities. Besides, data was collected from secondary sources (literature review, documents provided by the organization and data provided in the organizations websites) to provide more evidence on the current MaaS practice provided by the organization. Results from the secondary sources helps to compliment and provide data triangulation with the primary data from the interview.

The second phase entails choosing the interview type which can be semi-structured, open-ended, or closed ended interview. In this research semi-structured interview instrument was designed in formulating interview questions for the case study based on the specified architecture layers. The interview questions relate to the presented architecture (see Figure 5) were designed and iteratively refined by two interviewers (pre-tested) and was not pilot tested since the questions were more of practical questions and less of research questions. Additionally, step three involves carrying the interview sessions in the organization with the informants after getting permission and consent from each informant. Also, informants in the organization who currently implement mobility solutions for countries in Europe were contacted via their official email address. A letter which contains the overview and aim of the research accompanied with a covering letter was sent. A follow up email was sent out by the interviewer to confirm if the selected participants were interested in partaking in the interview session at the informants' convenience.

In step four the interview sessions were verbally recorded by manually writing down the response of the informants in relations to the multi-tier architecture for eMaaS operations. The interview sessions were carried out till saturation point was reached when no new data was gotten. Subsequently, step five entailed analyzing the interview response in relation to each layer of the architecture. Moreover, step 6 involved modelling each interview transcripts in the multi-tier architecture as seen in Figure 8 and 9. Also, in this phase a follow up emails were sent to a few informants to verify findings that has been modelled in the architecture. In Step 7 the modelled findings are discussed to provide answer to the research question to verify how to facilitate the acquisition, processing, analysis, retaining, and provisioning of mobility relevant data originating from several sources, such as position of EVs, routing, EV usage, charging stations, EV parking stations, battery charge condition of EVs, and public transport data (see Section 5.1.2 and 5.1.3).

4.7. Case Study Procedure

We employed a single-case study approach to get in-depth information about eMaaS in practice as it provides rich evidence and a clear description of theoretical models (Yin, 2013). Also, case study is well-suited to explore societal issues (Miles *et al.,* 1994) and help researchers to get a better understanding of how e-mobility services are deployed in real world scenarios (Yin, 2013). Data was collected through four in-depth, semi-structured interviews question related to the proposed multi-tier architecture to avoid biased responses with purposively selected experts chosen to provide data based on their experience in MaaS. Interviews was selected as the data collection instrument because it's highly efficient tool to carefully gather rich data that aids to identify both the technical aspects related to eMaaS implementation.

In conducting the case study data collection each informant is included for the data collection based on their experience in MaaS implementation in smart city. The informers who finally agreed and participated in the data collection session are showed in Table 1. The interview was conducted in English and face-to-face and was recorded manually by the interviewers. Data was collected from four experts from the company, where data was collected for an average of 2 hours in three different locations. The interview questions consist of seven main questions based on each layer of the architecture (see Figure 5).

Table 1 Overview of participants

#	Positions	Education	Years of Experience	Current Role for eMaaS
1	Chief architect	M.Sc.	>20	IT architect for energy transport solutions.
2	System Developer	B.Sc.	<5	Hardware testing, web socket, and interactive mobility application interface.
3	System Architect	M.Sc.	6-10	Front-end development of transport solutions.
4	Mobile Developer	B.Sc.	<5	Android mobile application transport solutions development.

Table 1 shows that data was collected from four informants as recommended by (Yin, 2013) who suggested that data should be collected from more than three informants in a single case study. The interview was performed face-to-face in a conversational style, opening with a discussion on the need for the proposed multi-tier architecture to support eMaaS in smart cities and then proceeded to the applicability of APIs and provision of mobility related data. Thus, the interview session was carried out by two researchers from the +CityxChange project (https://cityxchange.eu/) who presented the background of the architecture and discussed how each of the layers of the proposed multi-tier architecture can be applied to support eMaaS.

The participants were encouraged to comment and change freely everything concerning the multi-tier architecture during the discussion. After the interview session, one of the interviewers sketches a summary of the findings relating to the multi-tier architecture in relation to how e-mobility service is implemented in their current service. Subsequently, the interviewers sent a preliminary report to two of the interviewees in the company for commenting and follow up after which few iterations and corrections were made. The communication between the researcher and the interviewees about eMaaS was also strengthened with several email conversations to create synergy for the proposed multi-tier architecture (theory) and findings (practice) from the company regarding eMaaS. Therefore, response from the interview session was used to confirm the applicability of each layers of the proposed multi-tier architecture presented in Figure 5.

5. Demonstration and Evaluation (Findings)

This section presents the results of the case study representing the late phases of the designs science methodology to assess how the proposed multi-tier architecture performed in practice.

5.1. Overview of Case Study

The maintain the anonymity of the company the name of the infrastructure service provider is referred to as "Case Study A". The company provides a range of smart city, energy, and mobility products and services, such as an infrastructure platform for managing distributed mobility service for public transport establishments such as bus operators. Case study A has more than 10 staffs with its head offices in Trondheim, Norway. For the past 19 years case study A have obtained practical experience with development, deployment, and maintenance of distributed solutions that creates value to their clients. The company deploys solution such as energy system and Machine-to-Machine (M2M) technologies to deliver innovative business and IT functionality to end users. Based on the company's in-dept experience in mobility, the organization was selected as a case study to verify the applicability of the proposed multi-tier architecture.

5.2. Evaluation of the Proposed Multi-tier Architecture Layers

In reporting the findings, open coding schemes as suggested by Van de Wetering *et al.* (2018) was employed to analyze, organize and present the findings together with the outcomes of the literature to iteratively gain as much insight as possible to confirm the applicability of all layers discussed in Section 3. Therefore, Figure 8 and 9 d illustrates the application of the proposed multi-tier architecture in case study A current eMaaS and big data (history, real-time, online data) implementation.

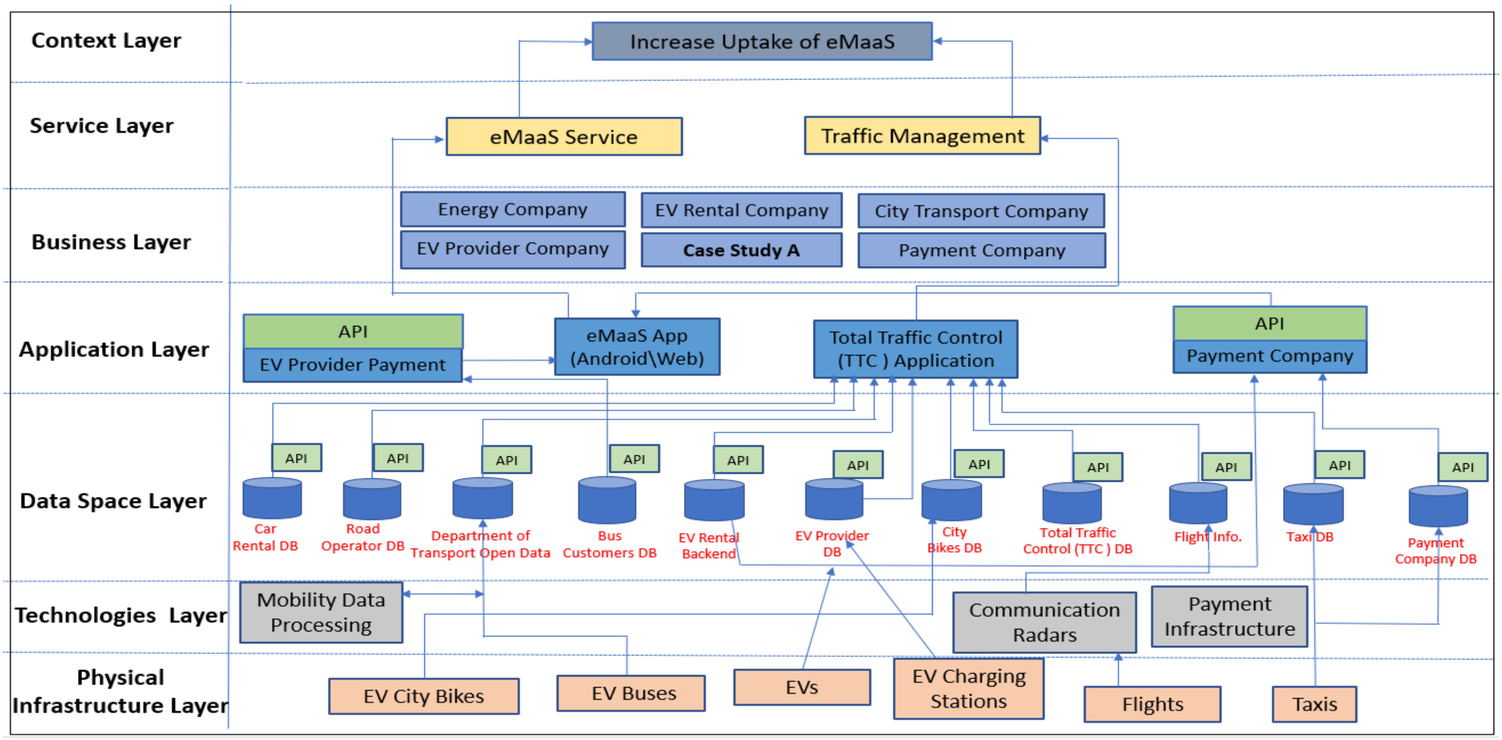

Figure 8. Applicability of the proposed multi-tier architecture

Figure 8 depicts findings on how case study A applied the proposed multi-tier architecture to increase uptake of eMaaS operations in smart city. Findings from the case study interview aids to verify each layers of the architecture as presented below;

5.2.1. Context

Case study A provides innovative technologies and business models that is in line with the ministry of transport plans to improve public transportation, decrease environmental pollution and lessen traffic by deploying IT in creating open-ness of mobility services. Case study A implements service-oriented method that reduces costs for IT solutions for public transport. Findings from Figure 8 shows that the context layer aims to increase intake of eMaaS in smart cities by using electric vehicles to aid in cutting local emissions from transportation. This finding confirms the relevance of the context layer as it main goal is to improve sustainable transportation in smart cities to aid reduce carbon dioxide emissions.

5.2.2. Service

Service layer comprises of eMaaS service and traffic management service, where both services are achieved based on the virtual collaboration of six different companies. Also, case study A implements an open service platform to support public transportation "as-a-service" in providing an economical public transport facilitated by cloud technologies. Case study A aims to move Norway mobility sector to an open booking solution by deploying an account identification-based ticketing system that uses identification payment as means of payment by collaborating with payment company to provide a standard Norwegian Quick Response (QR) code, Near-field communication (NFC) wallet solution. This is facilitated by payment backend that deploys a flexible open APIs which provide mobility related backend payment services.

5.2.3. Business

Case study A is mostly concerned with providing smart solutions for managing eMaaS in achieving zero-emission vehicles and smart energy solutions to attain 50% potential energy saving. This layer comprises enterprises involved in the e-mobility services which includes energy provider, EV provider, EV rental, city transport, payment, and case study A.

5.2.4. Application and Data Processing

Case study A currently utilizes an in-house web service cloud enabled backend system with a linked HTML 5 based Graphical User Interface (GUI) that deploys SQL database with business logic in Java that can be installed on transport company servers to implement eMaaS operations based on open transport data. This opens the possibility for custom and innovative mobility related applications for citizens and stakeholders such as transport service provider system that provide mobility data to citizens via external interfaces used to relay search queries. The application layer comprises of EV provider payment application, eMaaS application, total traffic control, and payment application deployed to support eMaaS operations. Moreover, this layer is facilitated by APIs which provides interoperability of data to EV provider payment application and payment application. Correspondingly in the eMaaS, EV sharing scenario a citizen needs to find a suitable EV in his/her immediate district by utilizing the eMaaS application android/web (as seen in Figure 8) to view a list available EVs. Thus, the eMaaS platform retrieves and makes use of Global Positioning System (GPS) to know the exact location of the citizen. Using the retrieved location data, the service selects EVs that meet the citizen's searched criteria and pushes the correlated data to the citizens' device. The citizens can then proceed to choose and reserve an EV using the service. Next the citizen proceeds to the parked location of the EV and as soon as the EV is on the move, the mobility service report current positioning and status in real time to eMaaS provider for EV fleet control.

5.2.5. Data Space

Findings from the interview reveals that the data space layer comprises of different data sources both open and private. As seen in Figure 8 data is accessed from the various data sources via APIs, where the data sources include data from car rental data source, road operator, bus customer, EV rental backend, EV provider, city bikes, total traffic control, flight information, taxi, and payment company. Thus, Figure 8 reveals that eMaaS utilizes public data such as schedules, routes, weather etc., as well as business data which includes ticket fees information, charging stations, etc., and private data citizens profiles, preferences, targets, etc.

5.2.6. Technologies

Case study A aims to transform citizens transportation services using expert software and hardware beams or cameras and sensors installed in EVs computers to detect, track, and count passengers anonymously using interactive maps. The technology layer comprises of e-mobility data processing (this component process data real-time data from physical devices as seen in Figure 9), communication radars and payment infrastructures. Furthermore, case study A deploys a messaging protocol "Advanced Message Queuing Protocol" (AMQP) that manages real time messages and forwards and stores queued message for handling mobility services (see Figure 9). AMQP offers a simple lightweight, open client server subscribe messaging transport protocol implemented to support e-mobility services (Zabasta *et al.,* 2018). It supports secure message transfers and formation of secure network connection via Secure Socket Layer (SSL). AMQP utilizes topics for disseminating data between subscribers and publishers deployed using JSON message string that wrap around messages being transferred between citizens and eMaaS application to enable data interoperability.

5.2.7. Physical Infrastructures

Lastly, the data source layer comprises of EV city bikes, EV buses, other EVs, EV charging stations, flight and taxis that generates real time data. Results indicates that this layer support generation of real-time and incremental processing of collected data to be used by eMaaS app and Total Traffic Control (TTC) applications. Moreover, the unstructured data produced from EVs are saved as files into Hadoop Distributed File System (HDFS). To facilitate data locality in data processing, SPARK and HDFS are deployed in same cluster, but internal processing deploys MapReduce functions to produce indexed views in CouchDB which stores all received mobility related data and execute simple data processing for historical data internally via HDFS. Whereas, Spark executes more intensive and scalable external data processing of real-time and online data produced.

5.3. Processing of History, Real-Time and Online Data

This section presents findings from the case study regarding how API, big data types (history, real-time, online data) are linked and what role they play to the general structure of eMaaS systems. Figure 9 shows mainly how to facilitate the acquisition, processing, analysis, retaining, and provisioning of mobility relevant data originating from several sources, such as position of EVs, routing, EV usage, charging stations, EV parking stations, battery charge condition of EVs, and public transport data. Thus, Figure 9 aims to provide answer to the research question posited in the introduction section of this paper.

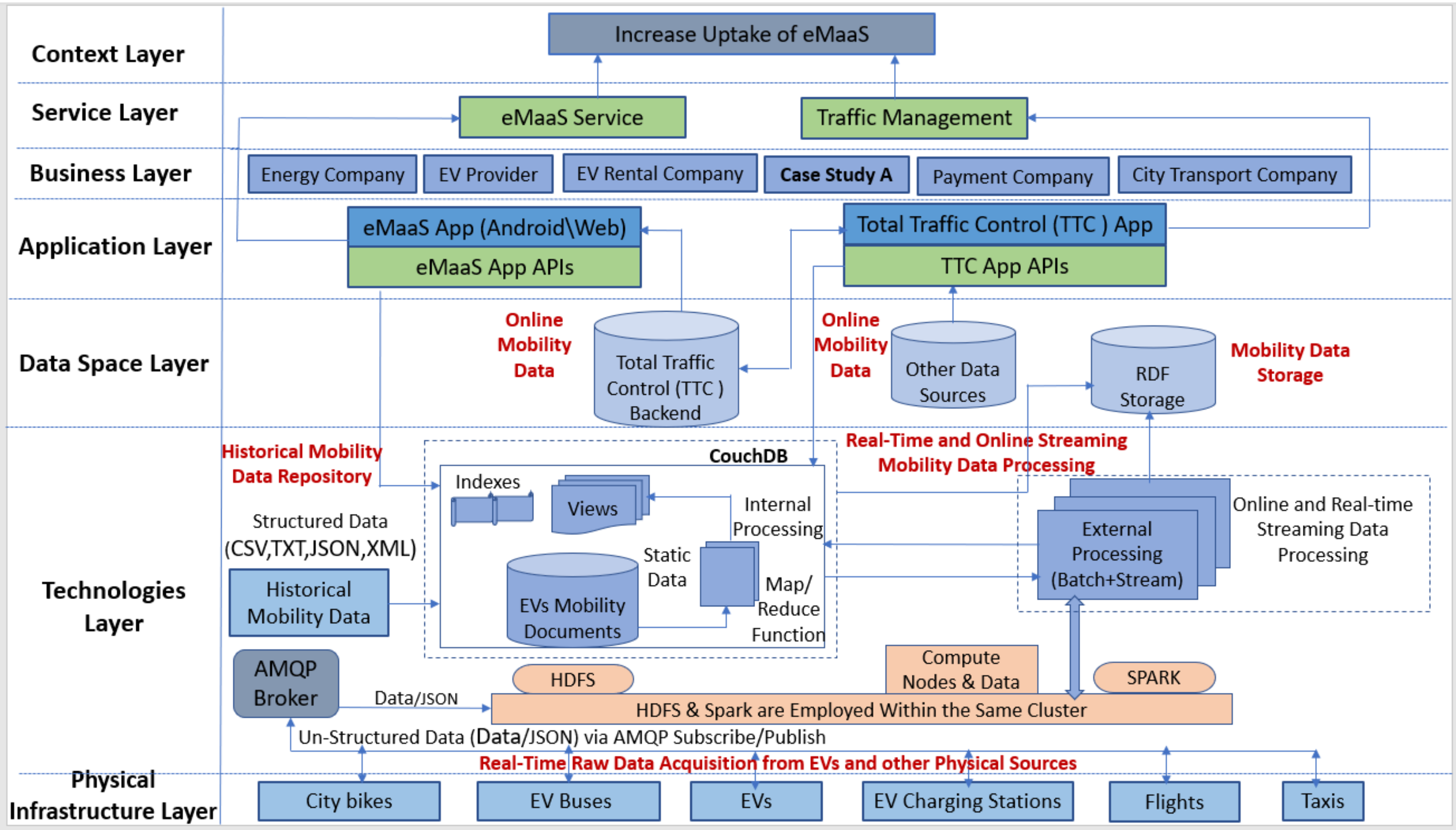

Figure 9. Mobility data (history, real-time, and online) processing in the architecture

Respectively, Figure 9 depicts how historical, online, and real time mobility data are processed and saved in Resource Description Framework (RDF) format. First, data with different formats are collected from EVs via AMQP broker and forwarded to be stored in the data repository HDFS based on subscribe/publish protocol. Thus, all mobility real-time data collected via EVs in the physical infrastructure layer are saved as JSON documents, mostly online data via various APIs (collected from the EV provider payment application, eMaaS application, total traffic control, and payment application in the application layer (see Figure 8)) and historical data (previously saved mobility related data provided by the transport company or municipality) are processed using MapReduce which reduces the files into small chunks to be consistently mapped across data nodes with different indexed locations.

Moreover, unstructured and semi-structured real-time data are collected, where the semi-structured data are EVs data saved in JSON format and unstructured data may be texts documents added by the transport company. The data are then processed by a set of pre-defined tasks internally, such as converting data into new formats or generating new structured tables/views to index data. Moreover, complex processing tasks, such as data aggregation which provides scalable and flexible processing resource are deployed by Spark cluster executed by large number of compute nodes. Next, CouchDB a NoSQL database was deployed as it can process the volume of big data generated from EVs. Besides, CouchDB utilizes API (see Figure 9) that facilitates direct read and write of e-mobility data.

6. Discussion and Implications

6.1. Discussion

Smart city solutions deployed are presently transforming data to services for citizens and businesses. These smart services such as eMaaS utilizes open and private data, static, online, and real time data collected from private operators and city administrators. However, eMaaS in smart cities requires the integration of data from different sources and processed into useful information deployed through services, utilized by citizens and businesses. This challenge entails the collection of enormous amounts of data aggregated in various formats, where the analysis of these data is important to deduce useful information. Moreover, the absence of a common and standardized platform that supports the provision and dissemination of such data severely limits the prospects of services that can be derived to benefit citizens.

Furthermore, findings suggest that the multi-tier architecture is applicable in managing eMaaS that are entirely based on real-time data in creating an eco-system of open mobility data that employs APIs to provide interoperable access to mobility metadata (that catalog and describes the data) and data sources (that point to internal open and external data resources). This finding is consistent with results from other studies (Abu-Matar and Davies, 2017; Tcholtchev *et al*., 2014). Additionally, findings indicate that APIs aids interoperability toward unifying different mobility systems to create open innovation platforms that provide a repository of metadata and data sources that provides light-weight access to information without e-mobility service providers having to worry about database size as data is only retrieved on demand.

6.2. Implications to Theory, Practice and Policy

Findings from this research has significant implications for theory, practice, and policy towards energy sector management. Theoretically, this study proposes a multi-tier architecture that utilizes mobility related data via APIs for transportation services in smart cities to support interoperability of different e-mobility services, thus developing a big data driven architecture that provides integrated information supporting services for decision support. The multi-tier architecture based on +CityxChange project to provide innovative eMaaS for e-mobility operators and citizens towards improving sustainable transport and e-mobility systems. Besides, findings reveal that the architecture is applicable in integrating information from different data sources to enhance citizens' engagement, increase awareness, and provide information for e-mobility development by transforming data into valuable knowledge and actionable information. Moreover, the multi-tier architecture integrates and exploit e-mobility data collected from transport company open data, private data from mobility operators, and personal data generated from citizens to provide solutions for interoperability of different e-mobility data sources.

Practically, APIs are utilized to provide point of entry or access to data as services via Graphical User Interface (GUI) used by citizens to query, inputs represented in a machine-readable format. APIs provide access to data in executing GET, PUT, DELETE, or POST, via Hypertext Transfer Protocol (HTTP) (Raetzsch *et al*., 2019), helping businesses open-up data and offers the ability to collect data from different sources, link, annotate and make the information obtainable and searchable. The architecture aims to realize interoperability and replication of e-mobility solutions within the two lighthouse cities and subsequent follower cities within the +CityxChange project supported by real-time, online, and static data processing saved in RDF format in NoSQL database for eMaaS. Likewise, the architecture employs openly available and external data through third-party APIs web services to provide insights for city transportation company in smart cities towards creating and disseminating public transportation information to improve mobility services.

Thus, for policy implications findings from the case study indicate that the proposed multi-tier architecture offers a solution that supports the openness of e-mobility related data collected from different operators for producing recommendations to citizens analogous to results from prior study (Bellini *et al*., 2018). Moreover, the multi-tier architecture deploys the processing of mobility data generated mainly from eMaaS application (web services), real time data from EV sensors, static or historical data in different format. Likewise, the data are collected from different providers for example from transport city operators, citizens, data brokers, etc. analogous to findings from prior studies (Zabasta *et al*., 2018). The processed and analyzed data are collected, processed and sequentially aggregated and saved. Then, the retained data are utilized to support decisions regarding e-mobility strategies for anomaly detection, analysis, early warning, prediction, suggestions, etc. to improve public transport services such as changing transportation schedule, changing traffic zone, regulating parking fee for citizens, etc.

7. Conclusion

Evidently research in smart cities is gaining prominence globally due to increase in urban population and transport infrastructure in cities. This has resulted to an increase in number of cars in urban environments that leads to pollution which pose serious threat to citizens health. Accordingly, to address these issues there is need to implement a collaborative vehicle sharing solution termed as eMaaS that deploy green transportation such as EVs (electric cars, Segway, electric bicycles, etc.). Thus, EVs plays a key role in improving sustainable transportation and reduction of carbon dioxide. Hence, the electrification of transportation has been prioritized in several European countries such as Norway, Finland, The Netherlands, etc. Although, EVs for eMaaS operate on data which is used among different citizens, stakeholders and entities. Apparently, an approach is required that enables the interoperability, sharing and management of mobility data to improve sustainable transportation in smart cities. Similarly, to improve e-mobility operations in smart cities there is need for an infrastructure that provides distributed storage and processing of huge volumes and variety of e-mobility related data generated at high velocity to provides value-added services to promote eMaaS.

Therefore, this study proposes a multi-tier architecture that stores, processes, analyze and provides data and related services to improve e-mobility within smart cities. The multi-tier architecture aims to support and increase eMaaS operation of EVs towards improving transportation services for city transport operators and citizens moving within the city to provide solutions for sustainable transport and e-mobility services. Decision science methodology using case study by interview was employed to verify the proposed multi-tier architecture. Data collected from four participants in a technology infrastructure company in Norway confirmed the applicability of the multi-tier architecture. Although qualitative data was collected to verify each layer of the architecture, there is need to utilize quantitative data either from survey or experiment to statistically test the applicability of the architecture. Similarly, data was collected from a single company in Norway, hence there is need to test the architecture with real case data collected from other transport service companies.

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