Post-print version of the paper by Anthony Jnr, et al. in Digital Policy Regulation and Governance, (2021) 1-26 https://doi.org/10.1108/DPRG-04-2020-0044

Digital Transformation with Enterprise Architecture for Smarter Cities: A Qualitative Research Approach

Bokolo Anthony Jnr*[1]., Sobah Abbas Petersen[2], Markus Helfert[3], Hong Guo[4]
anthony.j.bokolo@ntnu.no*[1], sobah.a.petersen@ntnu.no[2], markus.helfert@mu.ie[3], homekuo@gmail.com[4]

Department of Computer Science, Norwegian University of Science and Technology, NTNU, NO-7491 Trondheim, Norway[1, 2, 4]
Maynooth University, Innovation Value Institute, School of Business Maynooth, Co. Kildare, Ireland[3]

Abstract

Purpose

Smart city services are supported by Information and Communication Technologies (ICT) referred to as digital technologies which increasingly promise huge opportunities for growth but are faced with system alignment and data integration issues when providing digital services. Therefore, this study aims to employ Enterprise Architecture (EA) in digital transformation of cities by developing an architecture to address system alignment and data integration in digital transformation of cities.

Design/methodology/approach

Qualitative method is applied to evaluate the presented architecture based on electric-mobility (e-Mobility) scenario and data was collected using case study via interviews from a municipality in Norway to validate the applicability of EA for digital transformation of city services.

Findings

Findings from the interviews were represented in ArchiMate language to model the digital transformation of e-mobility in smart cities. Findings suggest that the architecture serves as a guide to recommend urban administrators of the potential of EA and digital transformation in addressing system alignment and data integration issues in smart cities.

Research limitations/implications

Data employed in this study is from a single case, hence there is a need to evaluate the application of EA for digital transformation of city services with data collected from multi-cases.

Practical implications

This current study adopts enterprise architecture approach to support city transformation as it has been widely applied by institutions to align business and ICT components.

Social implications

This study provide implication on how municipalities can utilize EA and digital transformations towards a sustainable smart city.

Originality/value

An architecture is presented that can be utilized as a guide to help urban developers and designers in deploying sustainable transport policies for smart cities. Additionally, EA is employed to foster digitalization towards achieving system alignment and data integration in cities to support urban environment as they digitally transform services provided to citizens.

Keywords: Smart cities; Digital transformation; Enterprise architecture; System alignment; Data integration; Qualitative approach.

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

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1. Introduction

The increased growth of urban areas has introduced cities with challenges in sustaining resident's quality of life (Giffinger *et al.* 2007). Hence, the growth towards smart cities has received momentum from the deployment of digital innovations which provides digital services to improve citizens life (Jnr *et al.,* 2018). This service evolution is facilitated by the innovative use of digitalization that is employed in new technologies utilized for smart services. With technological innovations and digitalization cities can actualize future social, environmental, and economic benefits (Hämäläinen, 2020). A smart city is a sustainable urban area where every part of urban services is supported by Information and Communication Technology (ICT) and governed in an effective way to manage mobility, energy systems, water and air quality, climate change, etc. (Mamkaitis *et al.*, 2016) A smart city can be referred to as a social system that brings together business, technology, and society. Understanding smart cities means recognizing the technological aspects as well as the human aspects (Bokolo and Petersen, 2019). In a smart city, citizens can securely gather, share, and manage information that relates to all aspects of their daily lives in a sustainable and ubiquitous manner (Mamkaitis *et al.,* 2016).

Digitally enabled cities are supported by ICT referred to as digital technologies which progressively promise huge opportunities for growth. These novel digital technologies employ ICT systems to provide a holistic view of city services. Such initiatives are referred to as digital transformation (Loonam *et al*., 2018). In urban environment digital transformation highlights the impact of IT on municipality's routines, information, structure, and organizational capabilities (Li *et al*., 2018). Accordingly, digital transformation which involves the integration of digital technologies into business processes has become increasingly important for cities seeking to achieve a sustainable society (Kaplan and Haenlein, 2019). Furthermore, digital transformation of cities comprises of different connected devices and systems that produce and transmit large amount of data (Heaton and Parlikad, 2019). As a result, many data sources are fragmented and exist in silos which impede provision of value-added services (Hjort-Madsen, 2006). Additionally, as data is being transmitted from the different heterogeneous systems, the ability to align these systems and integrate generated data seamlessly has becomes a major challenge.

But, without these systems being able to align and exchange data, digital transformation of cities could not be fully realized (Costin and Eastman, 2019). The lack of alignment and integration among system and data generated hinders value creation due to incompatibility and loss of data. System alignment and data integration is the ability of IT components to mutually function with each other and make use of data produced by various systems (Vakali *et al.,* 2014; Heaton and Parlikad, 2019). Thus, alignment and integration are basic functional requirement in smart cities due to different systems deployed in urban space (Gao *et al.,* 2014). Hence, there is need for an approach to support system alignment and data integration between different technologies to enable the seamless transfer of data across different stakeholders involved in providing digital services in smart cities (Psyllidis, 2015).

Therefore, Enterprise Architecture (EA) is seen as a suitable approach to manage complexity associated with heterogeneous systems and technologies (Anthony *et al*., 2019). EA can support cities to transform and digitalize public services. EA provides a medium to manage the overview of IT systems, data and align the IT strategy to the business strategy and the needs of the cities and citizens and thus serves as an informational foundation for informed decisions in urban development (Chen *et al*., 2008). Simultaneously, EA provides a means to develop and visualize to-be states of the city (Anthony Jnr *et al*., 2021). EA plays a critical role in this integration, aiding better designs for cities, management of their operations, and analysis of their performance (Kakarontzas *et al.*, 2014). Since its inception in the late nineteen eighties, EA discipline has progressed into a well-known initiative of managing Information Systems (IS) alignment with business goals (Gorkhali *et al.*, 2017). Therefore, EA comprises of models, principles, and methods used in the realization and design of cities IT infrastructure, business processes, and organizational structure (Jnr *et al*., 2021).

But, despite several research that focused on the role of EA in making cities smart, there have been few studies aimed at employing EA to address system alignment and data integration in capturing the data needed to support digital transformation of smart city services (Saluky, 2018). Accordingly, this research attempts to address the following research question:

RQ. How to support alignment and integration among different components operating in a city allowing stakeholders to collaborate in exchanging data via different systems for sharing resources and providing seamless digital services.

Therefore, the aim of this research is to present an EA framework to support cities in their efforts to address system alignment and data integration in providing digital services. Furthermore, the architecture helps to support digital services among different components operating in a city allowing stakeholders to collaborate in exchanging data via different systems for sharing resources and providing seamless services. The remainder of this study is structured as follows. Section 2 is literature review, and then section 3 presents the methodology. Section 4 is the modelling of findings. Section 5 is discussions and implications, and section 6 is the conclusion.

2. Literature Review

2.1. Background of Smart Cities

With rapid developments in ICT industry, technology is widely deployed in different parts of the society including cities (Jnr *et al.*, 2018). The application of ICT in urban environments is termed as smart cities (Hämäläinen, 2020). Thus, a smart city is a city that invests in social and human capital, transport, and modern ICT infrastructure for sustainable economic development and a high quality of life, with an increased management of natural resources, through involved governance. Hence, a smart city involves the integration of technological, administrative, and policy innovations (Mamkaitis *et al.,* 2016). According to the European Union (EU), a smart city refers to a place where traditional services and networks are made more effective with the utilization of digital and telecommunication technologies for the benefit of its residents and business (Hämäläinen, 2020). Additionally, the goal of smart city initiatives is to decrease the costs of city services, accelerate economic growth, improve return on investments, and transparency, as well as increase stakeholder participation in city governance (Hämäläinen, 2020). A smart city addresses the needs of citizens, institutions, and businesses and is composed of a well-constructed business plan, aligned with Information Technology (IT) to provide a platform for services integration (Bastidas *et al.*, 2017). An illustration of a smart city model is shown in Figure 1.

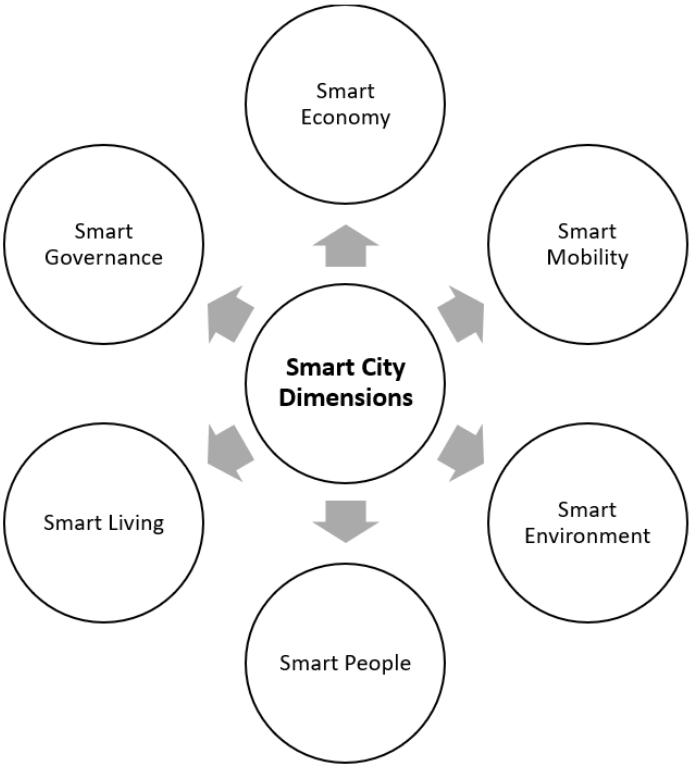

Figure 1. Illustration of smart city model adapted from (Giffinger *et al.* 2007; Anthony Jnr, 2021)

Figure 1 illustrates smart city model comprising of six main dimensions, where smart economy refers to economic image, entrepreneurialism, flexibility of the labour force, innovation, and the potential of a city to be transformed into a sustainable city (Giffinger *et al.* 2007). Smart mobility involves the availability as well as the accessibility of safe transport systems, green infrastructures, and modern facilities (Anthony Jnr, 2021). The smart environment refers to the protection of natural resources such as land, water, clean air, etc. for present and future use (Giffinger *et al.* 2007). Smart people consist of the inhabitants or communities at large that resides within the city. Smart people utilized digital services to improve their quality of life (Bokolo and Petersen, 2019; Jnr *et al.*, 2021). Smart living aims to improve citizens understanding of how technology interact societal development (Anthony Jnr, 2021). Finally, smart governance involves adopting ICT to support planning and decision-making for policy makers (Giffinger *et al.* 2007). However, this current study is more concerned with smart mobility by using an electric-mobility case to demonstrate the digital transformation of cities.

2.2. Digital Transformation in Making Cities Smarter

Digital transformation represents the novel use of digital technology (social, mobile, analytics, Internet of Things (IoT), platforms, and ecosystems) to solve traditional problems (Ansong and Boateng, 2019). Digital transformation can result to disruptive innovation, creation of value networks, and new markets (Kaplan and Haenlein, 2019). Digital transformation aims to trigger significant changes through combinations of information, computing, connectivity, and communication technologies (Vial, 2019). It is a multi-layered phenomenon that offers implications for different sectors (Bouwman *et al*., 2018). Presently, few cities see digital transformation as a means to enhance processes and reduce costs, while others perceive it as a prospect to create new value by offering new services (Tekic and Koroteev, 2019). In urban development, digital transformation highlights the impact of IT on a city's structure, operations, information, and administrative capabilities to deploy IT. Thus, digital transformation underlines the alignment between IT and businesses operations of the city (Li *et al*., 2018). In the electric-Mobility or e-Mobility sector, digitization has led to disruptive product innovations (e.g., autonomous vehicles), innovative business models (e.g., pay-as-you-go services and mobility-as-a-service within vehicles) and digital services (e.g., predictive maintenance and recommendations) (Dremel *et al*., 2017).

Furthermore, digitalization results in digital inter-connection of companies and people are accelerating several processes thereby increasing productivity. Researchers such as Endres *et al.* (2019) referred to digitalization as the fourth industrial revolution, which involve a change in IT, automation, and the move from offline to online services. Hence, municipalities are looking for novel ideas to better satisfy citizens' needs (Endres *et al*., 2019). One other movement in digital transformation is the generation of huge volumes of data, referred to as Big Data, that are collected which need to be properly managed. These huge quantities of data produced from systems (Volume) (Curwen and Whalley, 2018), at an increasingly high paces (Velocity) and the diverse systems from which data are produced (Variety), require advanced data management approaches (Pereira *et al.*, 2018). The use of digital technologies in smart cities aims to support the streamlining of urban processes, make city services more accessible to citizens and also improve resource management within the city (Bokolo and Petersen, 2019).

But, currently silo systems in smart cities have led to duplication of applications and databases that often require system alignment and data integration (Anthony *et al.*, 2019). One of the issues faced in digital transformation of smart cities is that different enterprises employ different platforms and thus it's challenging to align and integrate these applications to provide seamless interoperable services (Gorkhali and Xu, 2017). Thus, in this era of digital transformation, addressing system alignment and integration of processed data to be used for city services is a challenge. Therefore, an approach is required to help resolve system alignment and data integration for digital transformation in making cities smarter.

2.3. System Alignment and Data Integration

With growth in urban population there is need to deploy transformative approaches in cities to maintain a sustainable, healthy, and safe environment (Jnr *et al.*, 2020). The vision of digital transformation of cities aims to utilize smart technologies to achieve seamless data exchanges between various system deployed for city services (Costin and Eastman, 2019). Hence, system alignment and data integration are important for digital transformation of cities (Javidroozi *et al.*, 2015). Accordingly, system alignment is the ability for two systems to recognize one another and to utilize resources from one another (Heaton and Parlikad, 2019). System alignment implies that one system performs an operation while being connected to another system (Chen *et al.*, 2008). Alignment refers to harmonious or compatible relationships between two domains. Also, alignment refers to the fitting and linking between different components working together to achieve a common objective (Magoulas *et al.*, 2012). In city context, it is the ability for two heterogeneous systems to grant access to their resources and function jointly in a mutual way. Likewise, data integration is the process of ensuring the interaction between different entities necessary to attain domain objectives (Hjort-Madsen, 2006; Chen *et al.*, 2008). Respectively, integration refers to software that enables components of different applications to interoperate, specifically to be able to share data, function, and communications across services in different environments (McNabb and Barnowe, 2009).

In smart city environment data integration can be approached in various levels and manners, such as in physical integration (interconnection of data from IoT devices, sensors, metering devices, etc., through computer networks), application integration (integration of data from database systems and software applications) and enterprise integration (co-ordination of data needed for control, monitor, and manage business processes) (Chen *et al.*, 2008). A few studies have been carried out that explored alignment or integration of systems in smart city context. Among these studies Heaton and Parlikad (2019) designed a framework for alignment of infrastructure assets to improve citizen requirements in smart cities. The framework mainly helps in designing and developing smart solutions to deliver value to citizens. Kong and Woods (2018) explored the ideological alignment of smart urbanism highlighting the role of citizens and government in designing urban futures. Javidroozi *et al.* (2015) proposed a smart city systems integration model to provide access to real-time data and offer flexibility for creation and provision of efficient services.

Psyllidis (2015) presented an approach based on ontology that provides data integration from heterogeneous urban systems in smart cities. Gao *et al.* (2014) employed a semantic discovery approach to automatically integrate heterogeneous sensor data streams. Vakali *et al.* (2014) examined data streams integration in smart cities based on social data flows and IoT devices. Also, Nemirovski *et al.* (2013) investigated data integration based on ontology for distinct schemas of individual data sources in smart city. The reviewed studies did not address both system alignment and data integration in smart cities. Besides, enabling system alignment provides a scalable platform for data processing and analysis in deploying digital city services for citizen's requirements (Heaton and Parlikad, 2019).

To address the issue posed by different data silos across city systems, there is need for a method that demonstrated how cities can integrate urban data from different aligned systems. One approach that enable system alignment and data integration is enterprise architecture, which has not been employed by the reviewed studies. Accordingly, there is need for an EA framework to manages different urban systems (e.g. mobility, energy, water, buildings, waste, etc.), different data types (e.g. spatial statistics, sensor data, social data etc.) (Psyllidis, 2015). Hence, this study adds to body of knowledge to adopt EA in urban context to aid in the digital transformation of cities in addressing to support alignment and integration among different components operating in a city allowing stakeholders to collaborate in exchanging data via different systems for sharing resources and providing seamless digital services.

2.4. Enterprise Architecture for Digital Transformation of Cities

Cities are employing IT to digitally transform services provided to citizens and IT has become an important part of urban processes which has led to issues such as system alignment and data integration. Thus, there is a need to describe digital transformation activities in a less complicated approach to stakeholders. To address these issues faced in digital transformation of cities, this study employs the EA perspective. In IS domain, an architecture refers to a diagram that depicts the relationship of stakeholders' opinion to processes and data that support business operations (Lnenicka *et al.*, 2017). According to the ISO/IEC/IEEE 42010 standard, an enterprise architecture refers to a model that describes the fundamental properties or concepts of an enterprise environment, relationships among its components and principles of its design and evolution (ISO, 2011). EA was first announced by Zachman in 1987 as "IT architecture" and was adopted by government, military, and businesses (Bakar *et al*., 2019), as an important tool to help system developers and designers understand complexity.

Thus, EA frameworks are logical structures in consistent expressed language for organizing and classifying complex information and data sources. Hence, an EA framework can be referred to as conventional practices and principles for the description of architectures established within a particular domain (ISO, 2011; Xue *et al.,* 2019). In smart cities, EA can support better communication and sharing of information between stakeholders (enterprises, municipality, and citizens) in providing improved digital services delivery. One of the existing EA frameworks is the Zachman EA which defines the role a stakeholder may take, including named owner, builder, planner, designer, and subcontractor, and also represents the several aspects that should be considered. The Zachman EA framework also comprises of Who (people), What (data), When (time), How (function), Where (network), and Why (motivation), as the basis for complex system description (Xue *et al.*, 2019). Another EA framework is the Department of Defense Architecture Framework (DoDAF) that provides visualization structure for specific stakeholder's concerns via viewpoints structured by various views to provide a uniform framework to address interoperability issues faced among complex systems based on a net-centric, information-centric, and data-centric architecting (Xue *et al.,* 2019).

Likewise, the Federal Enterprise Architecture (FEA) is another EA framework based on business model initiative developed to provide a mutual framework for improving federal government processes such as horizontal and vertical information sharing, cross agency collaboration, performance integration, budget allocations, performance measurement, etc. The FEA aims to help institutions become a more citizen-centered, client focused government that maximizes savings to better attain mission outcomes (McNabb and Barnowe, 2009). Next is the Generalised Enterprise Reference Architecture and Methodology (GERAM) which was designed in 1990 mainly for enterprise integration. It was designed to support practitioner in combining different methodologies or frameworks in order to achieve a custom new architecture design comprising of reference architectures, techniques, modeling languages, and tools (Magoulas *et al.*, 2012). Similarly, The Open Group Architecture Framework (TOGAF) is one of the most widely adopted EA framework and is developed by the Open Group aimed to create a global open standards and interoperability to aid access to integrated information between and within enterprises (Saluky, 2018). TOGAF is defined by an Architecture Development Method (ADM) which comprises of closely inter-related architectures (business, information systems, and technology), strategy & motivation, and implementation & migration (The Open Group, 2011; Anthony *et al.*, 2019).

In regard to system alignment and data integration in digital transformation of cities Zachman does not provide adequate orchestration concerning how data requisites such as quality, availability, comparability, consistency, etc. are addressed. Also, TOGAF does not provide adequate guidance on how to avoid data inconsistency but promote sharing of available data. Lastly, GERAM, DoDAF, and FEA does not provide adequate management on how to align stakeholders to system components capabilities within an enterprise environment (Magoulas *et al*., 2012). Furthermore, a few studies employed EA frameworks in smart city domain. Among these studies Anthony Jnr *et al.* (2020) developed a layered architecture that employed API for urban energy management towards providing energy data to support decision-making on energy sustainability in enabling prosumption operations. Anthony et al. (2019) presented an architecture based on big data to enhance energy prosumption in smart districts by applying EA approach grounded on TOGAF.

Likewise, Pourzolfaghar *et al*. (2019) designed an EA framework to address the concerns of stakeholders in smart cities. Xue *et al.* (2019) employed DoDAF to develop an information EA to support smart transportation system. Moreover, Saluky (2018) developed an EA model for smart cities based on TOGAF to provide solutions to issues faced by cities. Similarly, Tanaka *et al.* (2018) proposed a framework for governance of ICT targeting smart cities focusing on EA based on TOGAF. Bastidas *et al.* (2017) identified important requirements of EA in smart cities to be used to compare and review current smart city frameworks. Mamkaitis *et al.* (2016) contributed by reviewing smart city frameworks from an EA perspective. Lnenicka *et al.* (2017) proposed a conceptual framework that analyzed the requirements of big and open linked data analytics in smart city ecosystem. Kakarontzas *et al.* (2014) developed a conceptual EA framework to specify important functional and quality requirements for smart cities.

Therefore, unlike previous EA approaches, this study aims to offers an EA framework that not only address data integration similar to prior studies but also considers system alignment, allowing data from different urban systems, virtual enterprises, etc. for digital transformation of cities. Also, the reviewed studies adopted EA approaches to make cities smarter. However, none of the study addressed system alignment and/or data integration issues faced in digital transformation of smart cities. Hence, there is need for a study to address this gap in knowledge since the data and stakeholders' perspectives which are important for seamless smart services are not fully considers in urban environment. Evidently, little is known about system alignment and data integration in digital transformation of cities in becoming smarter in providing digital services to citizens and stakeholders.

3. Methodology

3.1.Developed Enterprise Architecture for Digital Transformation

To address integration and alignment issues faced in digital transformation of cities in being smarter, EA is employed. Accordingly, this study presents an EA framework inspired by TOGAF. The presented EA framework is shown in Figure 2.

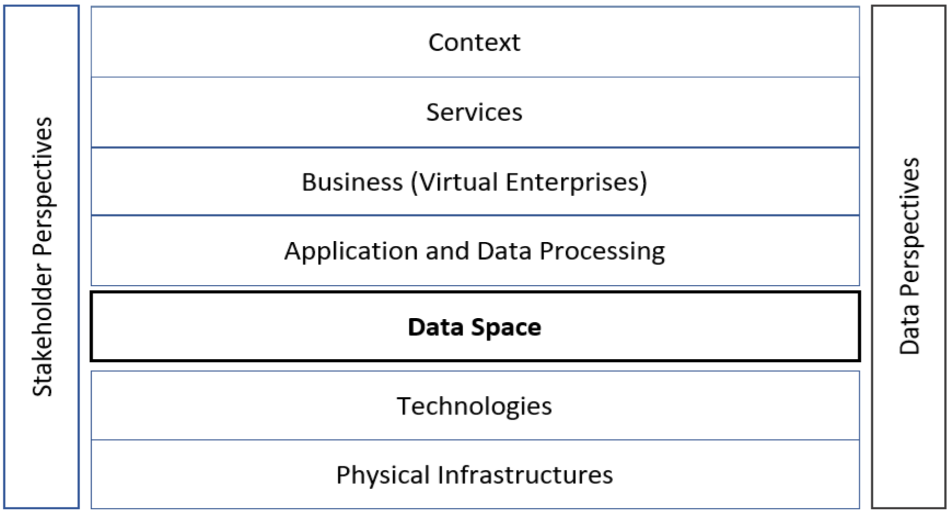

Figure 2. Developed architecture

Figure 2 depicts the developed EA framework to address system alignment and data integration based on the seven layers (context, service, business, application and data processing, data space, technologies, and physical infrastructures), and perspectives (stakeholder and data). The context layer entails desires, need and requirements that relate to stakeholders' concerns, and associated Key Performance Indicators (KPIs) that improve quality of life (Petersen *et al.*, 2019; Jnr *et al.*, 2020). This layer comprises of the set of goals, constraints, principles, and main requirements related to smart city initiatives (Anthony *et al.*, 2019). The context layer also captures the interests of city stakeholders and citizens (Pourzolfaghar *et al.* 2019). The service layer is responsible for presenting the city's action plans, resources, and capabilities. It consists of high-level processes provided by the city facilitating enterprises collaborating to provide new services to citizens (Berkel *et al.*, 2018). Thus, this layer aims to effectively implement specified outputs and competently realizing specified key performance goals (Anthony *et al.*, 2019).

The business layer is responsible for capturing all partners or enterprises collaborating to providing functions, and orchestrating processes to deliver digital services to citizens. Business layer involves operational activities that provide and deliver business services (Berkel *et al*., 2018). Thus, this layer involves virtual enterprises that cooperate in providing smart services to citizens to support in making city smarter (Anthony *et al.,* 2019). The application and data processing layer encompass all systems used to provide services to citizens and stakeholders. This layer uses data from the data space layer in providing services (Anthony *et al*., 2019). Moreover, this layer processes and transforms data into useful information to provide insights and smart services (Berkel *et al*., 2018). Hence, this layer provides applications that expose smart services to support the actualization of smart city operations (Anthony Jnr *et al.,* 2020). The data space layer is the intelligence processing of the architecture as it includes data required to facilitate smart services (Otto *et al*., 2017). Additionally, data space layer specifies which data is available and are utilized by the enterprises in providing smart services (Petersen et al., 2019).

The data space layer consists of real-time raw data (directly from the devices and sensors), processed online data from applications deployed in cities, analyzed historical data and lastly third party data (for external sources) (Anthony Jnr *et al*., 2020). Moreover, data space layer contains non-relational and relational databases that support city operations. The technologies layer entails all the technologies deployed across the city such as ubiquitous computing, big data, processing, cloud computing, service-oriented architecture, etc. This layer provides the required software and hardware infrastructures needed to provide smart services (Berkel *et al.,* 2018). This layer consists of infrastructures needed to collect, process, handle, and temporarily store real-time data. Also, this layer deploys either cloud-based or locally run servers. The physical infrastructures layer comprises of physical assets within the city (Berkel *et al.,* 2018). Physical infrastructures layer produces enormous real-time data generated from physical sources that is transferred to the technology layer (Petersen *et al*., 2019). The physical infrastructures consist of sensors, metering devices, IoT devices, sensing devices (e.g. smart card readers, weather sensors, Radio frequency Identification (RFID) chips tags, etc.) deployed within the city that generates real-time data (Anthony *et al*., 2019). Data can also be collected from online sources such as social media.

As shown in Figure 2, in addition to the horizontal layers, the developed EA takes into account the stakeholder perspective and data perspectives which contributes to help achieve system alignment and data integration in digital transformation of cities. The stakeholder perspective ensures a citizen focused approach and the participation and collaboration of several public and private entities call for close attention to the diverse stakeholders (e.g citizens, municipalities, enterprises, etc.), that are a part of the city-wide EA space. This perspective can also ensure awareness of the relevance of privacy and trust, data ownership and access, on the policies and regulations related to digital services provided. Similarly, the data perspective envisaging value added services that leverage on data that is available from both inhouse and other sources (e.g. open data), the data perspective relates to all layers of the EA, from the data sources to the value added services. Of particular attention here would be data interoperability, data standards, security, risk assessment, and data governance.

3.2.Qualitative Approach

This study adopts qualitative methodology by employing case study approach to collect data as previously adopted in the literature (Beaume and Midler, 2009; Mäkelä and Pirhonen, 2011), and data was collected using case study by interview from a municipality in Norway to practically verify the developed architecture (see Figure 2). Case study approach is employed in this study to get in-depth information (Yin, 2004), about the architecture layers in respect to e-Mobility services (Anthony Jr, 2018). Also, case study is selected as its well-suited to explore societal issues and help academicians to get a better understanding of how digital transformation is deployed in real world scenarios (Junior *et al.*, 2018). Data was collected through an open-ended interviews discussion related to the presented architecture to avoid biased responses, data was collected from purposively selected experts that have prior experience in e-Mobility, digital transformation in smart cities and the role of EA. As seen in Table 1 the participants included data scientist, 2 IT architect, a project leader, and a project coordinator which totaled to 5 interviewees.

Table 1 Overview of interviewees

#	Current Position	Education	Years of Experience	Current Role and Responsibilities
1	Data scientist	M.Sc.	>13	• Designs enterprise architecture for smart city services. • Creating data-based analysis for sustainable future.
2	Project leader	PhD	>20	• Work on implementation of low-emission electric vehicles and fossil-free vehicle and fleet platforms. • Design polices for electromobility, green infrastructure and sustainable urban transportation.
3	IT Architect	M.Sc.	>7	• Project team lead on city integration platform. • Integration development and architecture. • Urban requirement analysis.
4	Project co-ordinator	M.Sc.	>10	• Co-ordinates smart and sustainable cities strategies.
5	IT Architect	PhD	>20	• Develop digital services in smart cities. • Leads smart city integration and enterprise architecture modelling.

Table 1 depicts that data was collected from five interviewees as recommended by (Yin, 2013; Jnr *et al.*, 2019) where the authors suggested that data should be collected from more than three interviewees in a single case study. The interview comprises of seven key questions as regards to the architecture layers in relations to how the architecture can be applied to capture, and model systems and data sources needed to support digital transformation of eMobility in a city. Also, an open discussion was adopted where more questions were raised based on the replies of the interviewees. The feedbacks from the interview sessions captured how the organization planned to implement the electric mobility services in Norway.

The interview was performed within December 2019 two times via face-to-face involving three other researchers. Hence, in this study qualitative data was collected using case study by interview from a city in Norway that is digitally transforming their city transport services to e-Mobility. Accordingly, findings from the interview discussion was utilized to verify the relevance of each layers of the presented architecture. The collected feedback during the interview session is demonstrated or presented within the developed architecture (see Figure 4), to confirm the relevance of the architecture layers to address system alignment and data integration during digital transformation of e-Mobility service in a city in Norway.

3.3.Background of Case Study

To maintain anonymity, the establishment will be referred to as case study X. Case study X was selected for this study because it aims to reduce greenhouse gas emissions from transport to 85% in 2030. Case study X targets to give priority to a coordinated and holistic development of transportation within the city to ensure green shift by deploying environmental policies to promote bicycle, walking, and public transport to lessen car traffic. Case study X is working to be a driver for developing national measures in implementing necessary emission decrease measures by deploying new renewable transport solutions. As at 2019, electric cars usage sales in the city rise to 49% and about 9% car used in the city was electric as at 2018.

Besides, from August 2019, all city buses (about 300) utilized in Case study X were fossil free for environmentally friendly mobility. The buses provided by Case study X run on green energy alternatives to fossil fuels such as electricity, biodiesel and biogas, while the city metro bus uses a hybrid solution of electricity and biodiesel which do not emit CO_2 to the atmosphere. Also, mobile charging station are provided for the electric buses which are fully charger within 5 minutes. Also, in making the city smart, case study X uses available data and technology for sustainable prioritization of resources. Case study X opens up the city's open data and open interfaces to foster sustainable decision making and improving citizen involvement in development work and decision-making processes.

3.3.1. Overview of e-Mobility

Climate change and transportation have always been interrelated. e-Mobility concept has been projected to be a feasible sustainable medium to address future urban transportation challenge (Jnr *et al.,* 2020). e-Mobility refers to the concept of utilizing in-vehicle information, electric technologies, and connected communication infrastructures to achieve electric propulsion of vehicles and fleets. e-Mobility provides different travel option accessible through a centralized application for searching, bookings and payments. Citizens can choose and combine the most suitable alternatives for various transportation trips and needs. Thus, e-Mobility involves the digitization and synergies among electricity, mobility, and ICT in smart cities.

eMobility decreases air pollution in urban areas, reduces noise and avoids health issues, and potentially uses environmentally friendly electricity produced from renewable energy sources to charge the batteries (Anthony and Petersen, 2019). e-Mobility comprises of Electric Vehicles (EV), which is a vehicle that does not use gasoline as an energy source. Instead, it is powered by an electric motor that utilizes a stored battery to provide electricity as a form of green transportation as there is no pollutant produced by the car (Liu *et al.,* 2016). EVs include e-cars, e-bikes, e-scooters, e-buses, and e-railway. But in order to achieve e-Mobility services, system alignment and data integration (Schuh *et al*., 2013), are required to facilitate interaction between various stakeholders and enterprise systems, e.g. energy suppliers, car rental, e-Mobility service providers, charging station operators, and EV users is essential.

4. Modeling of Findings

4.1. Enterprise Architecture Modelling Language

EA modelling is a technique utilize to understand and represent the behaviour and structure of an enterprise. Digital transformation of smart cities is faced with issues such as system alignment and data integration thus EA modelling can be employed to consolidate how EA framework can be employed to address these issues. Currently, several EA modelling languages can be found in literature such as ADOxx metamodeling platform, Archimate modelling language, 4EM, ADOIT EA management tool, Cumbia, etc. In this study, ArchiMate EA modelling language version 4.4.0 is used because ArchiMate is an open source tool and is extensively utilized in industry (Tanaka *et al*., 2018). Secondly, ArchiMate has a stakeholder extension (Berkel *et al*., 2018), which aligns well with context layer in the presented architecture. Moreover, ArchiMate is a model-based tool that provide a graphical language for depiction of EA over time (i.e., including planning, transformation, and migration strategy), as well as the rationale and motivation for the architecture (Tanaka *et al*., 2018). Thus, ArchiMate is an appropriate modelling tool for describing digital transformation in smart city since it provides an inbuild business, application, and technology layers.

4.2. e-Mobility Case Implementation and Evaluation

The EA framework and the modelling approach facilitates a systematic and structured approach to provide an overview and visualize the complexity of the different entities that are involved in such smart services in digitalization of city services. Findings from the interview data is illustrated as the e-Mobility scenario captured in the developed EA (see Figure 3). The results aim to digitally transform e-Mobility services to create improved conditions for sustainable urban transportation that lessens CO_2/NO emissions. Accordingly, Figure 3 depicts findings from the interview represented as a Meta-model in ArchiMate aimed at illustrating how system alignment and data integration of e-Mobility service can be achieved. A bottom top approach is employed in modelling similar to prior study (Pradhan *et al*. 2018).

As can be seen from physical, technology and data space layers, the different technologies and data are made available by several actors (in business layer). They may be the owners or managers of the entities, the data providers, data consumers or users of data in different ways, using several applications to provide various services, for stakeholders along the different horizontal layers (the stakeholder perspective as explained in section 3.1).

Additionally, there are the numerous data sources and the applications which are a typical challenge, scaled up enormously due to the different actors that are associated with each of these. The data perspective can help to address interoperability issues, accessibility, and security issues. Similarly, the business layer shows that the city (municipality) must collaborate with several other virtual enterprises (most of which are private enterprises) to be able to provide the set of digital services that contribute to meeting the citizens' need for an e-Mobility service.

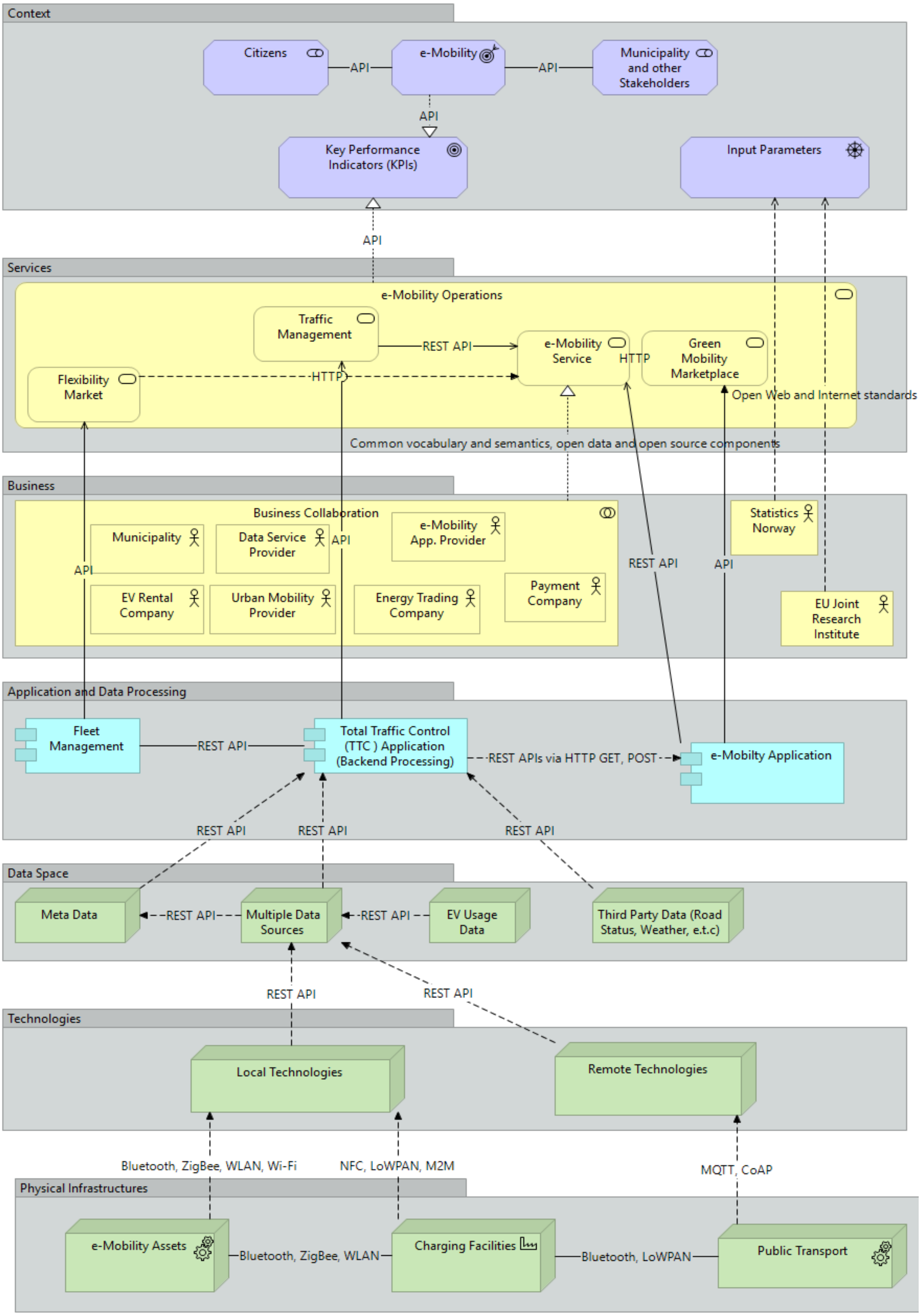

Figure 3. Meta-model for system alignment and data integration of e-Mobility service

Each of the layer is discussed below to show how systems are aligned and data is integrated for digital transformation of e-mobility service.

Post-print version of the paper by Anthony Jnr, et al. in Digital Policy Regulation and Governance, (2021) 1-26 https://doi.org/10.1108/DPRG-04-2020-0044

4.2.1. Physical Infrastructure Architecture

Findings from the interview confirm that this layer generates real-time heterogeneous data collected in aggregate from the devices that is transferred to the technology layer for further processing. Hence, this layer comprises of all the physical facilities which are required to gather data from equipment and IoT devices needed for e-mobility services.

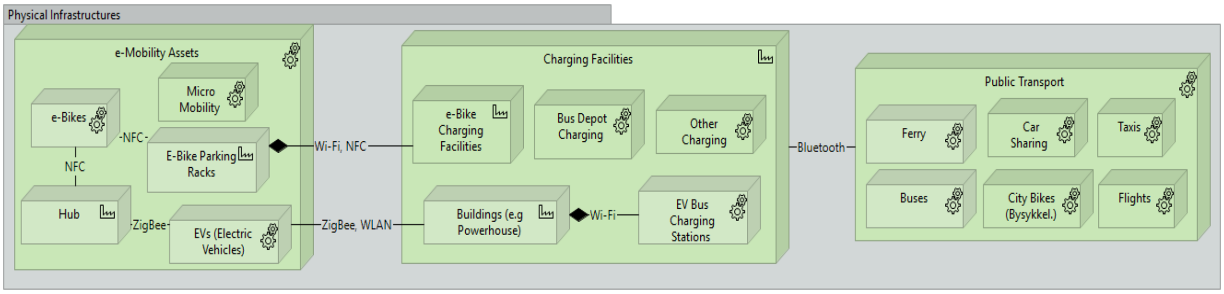

Figure 4. Meta-model for physical infrastructures system alignment for e-Mobility service

As seen in Figure 4 the physical infrastructures layers comprise of e-Mobility assets, charging facilities, and public transport that generated data that is forwarded to the technologies layer which comprises of local and remote technologies. The infrastructure used to align the system and to integrate the data in this layer comprises of electric vehicles, charging stations which are connected using network communication such as Bluetooth, ZigBee, WLAN, Wi-Fi, Near-field communication (NFC), LoWPAN etc. The infrastructure also connects to data sources using machine-to-machine (M2M) connection, Message Queuing Telemetry Transport (MQTT), and Constrained Application Protocol (CoAP) which enables systems or devices such as "nodes" to communicate with other devices deployed using similar protocols.

4.2.2. Technologies Architecture

This layer describes how the infrastructure related to the business, application, and data layers are organized by providing a technical reference layer that align the physical infrastructure which include local and remote technologies.

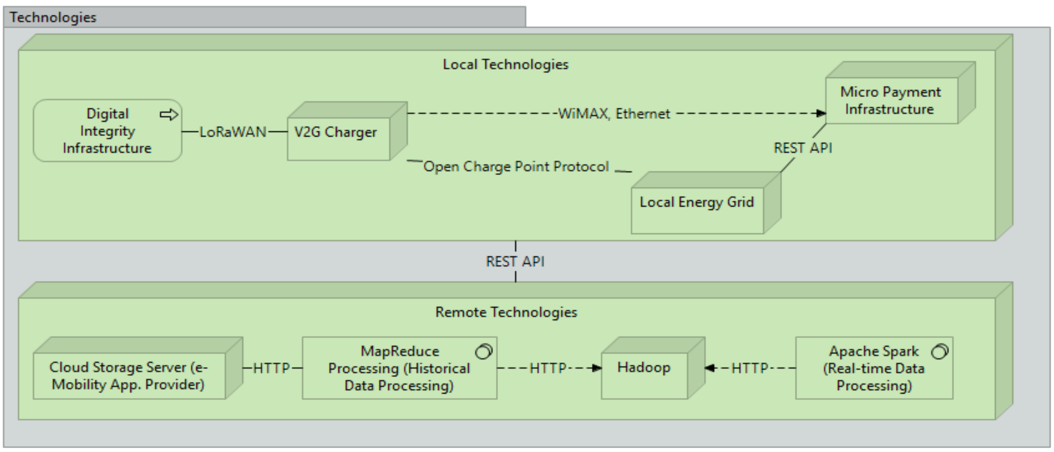

Figure 5. Meta-model for technologies system alignment for e-Mobility service

As seen in Figure 5 the local technologies include digital integrity infrastructures, Vehicle-to-Grid (V2G), micro payment infrastructure, and local energy grid. Whereas, the remote technologies include cloud storage server, MapReduce, Hadoop, and Apache Spark for processing or real time and historical data from the devices, sensors, and metering devices. The technologies connect via Representational State Transfer (REST) APIs via Hypertext Transfer Protocol (HTTP) to align the system and are deploy using protocols such as Open Platform Communications and Open Charge Point Protocol and LoRaWAN (V2G), WiMAX, Ethernet to integrate real-time data.

4.2.3. Data Space Architecture

The data space layer comprises of meta data, data from various sources, data from EVs, and lastly data from third parties such as road traffic status, weather forecast, etc.

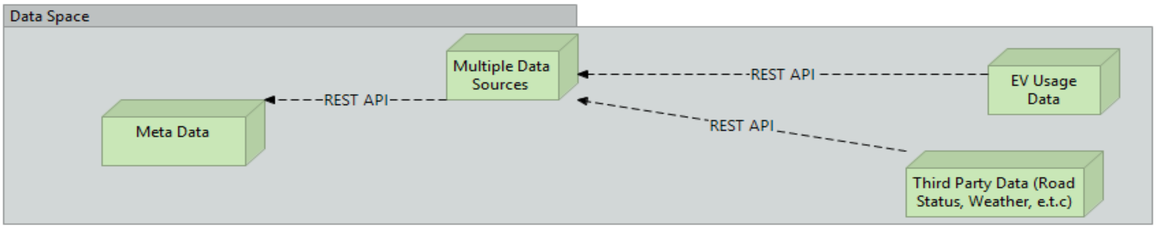

Figure 6. Meta-model for data space integration for e-Mobility service

As seen in Figure 6 this layer describes how the city data repository are organized, accessed, and identifies where significant blocks of information, are retained and how they can be accessed. Hence, the data space is an open data repository that provide meta data, real-time\online data, and historical data to enable system alignment and data integration, offering inventive opportunities for open digital services via open and linked data. Data from social media, the department of transport, weather data, airport data, taxi data, city transport data are among the data employed. Also, historical data on past transport and mode of transport are also used for prediction by the municipality in Norway to support e-mobility services. The data are provided in JavaScript Object Notation (JSON) and Extensible Markup Language (XML) format to be easily processed to support the city services or operations. The data are saved in structured database such as Microsoft excel (CSV), TXT, MySQL, PostgreSQL, and unstructured database such as NoSQL databases (such as Couch, Oracle, Mongo, Cassandra, etc.). Also, data from the e-mobility application is saved in MariaDB to be used in provide value added services to citizens and in improving digital services.

4.2.4. Application and Data Processing Architecture

This layer defines the types of applications that are required to process e-mobility related data.

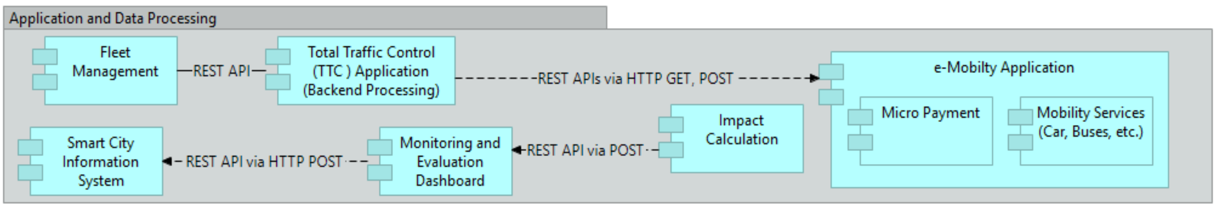

Figure 7. Meta-model for application and data processing integration for e-Mobility service

As seen in Figure 7 the application layer involves how data is processed and utilized by several applications in the “application and data processing layer” which comprises of the e-Mobility application used by citizens to manage transport booking that is aligned to the total traffic control application which is also aligned to the fleet management system. This layer also comprises of the monitoring and evaluation dashboard, impact calculation and the European smart city information system. The applications are aligned using REST APIs via HTTP GET, POST protocols and web sockets for carryout SQL queries to CReate, Update and Delete (CRUD) operations. The applications integrate metadata and multiple data sources for processing via REST over HTTP protocol for the Total Traffic Control (TTC) backend application in providing digital services to citizens via APIs and the application are used in mobile devices via cellular networks, 3G/4G/5G, LTE, or Wi-Fi.

4.2.5. Business Architecture

The findings confirm the business layer which involves several types of stakeholders such as policy makers, citizens, businesses, etc.

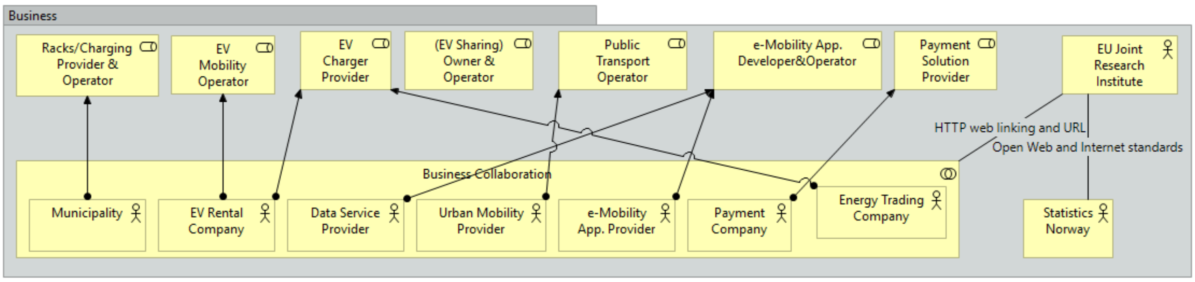

Figure 8. Meta-model for business (virtual enterprises) integration for e-Mobility service

Additionally, as seen in Figure 8 findings suggest that the business layer comprises of all the partners involved that collaborates to actualize the digital transformation of e-Mobility services such as the municipality, EV rental company, data service provider, urban mobility provider, e-Mobility application provider, payment company, and energy trading company. As well as statistics Norway and EU joint research institute. Besides, the role of each partner is illustrated. In the business layer virtual enterprises collaborates in providing e-mobility services such as EV rental, EV charging, EV parking, billing, etc. These enterprises are all integrated using common business standards and data must be made available in files in standard formats. The data source to be integrated should be built over open industry standards, allowing to create a vendor neutral and interoperable eco-system. Also, create and using a business data dictionary to ensure consistent understanding of data across the eco-system. Moreover, HTTP web linking and Uniform Resource Locator (URL) standard to leverage Open Web and Internet standards, are used to ensure that various deployed system from partners are alignment with data provided via well-defined REST APIs integrated to provide real time data via eMobility application to citizens.

4.2.6. Service Architecture

Findings reveal that the service layer involves smart city operations that relates to diffusion of digital activities within smart communities. Thus, partners in the business layer all collaborate to provide e-Mobility operations (flexibility market, traffic management, green mobility marketplace, and e-mobility service) as shown in the Figure 9.

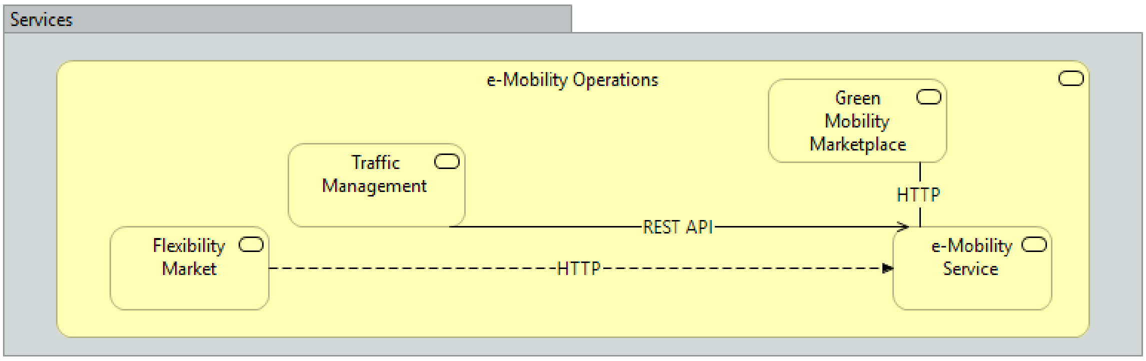

Figure 9. Meta-model for services integration for e-Mobility service

The e-Mobility operations in the service layer aims to provide e-Mobility to citizens, municipality, and other stakeholders as seen in the context layer based on other external parameter inputted by the municipality administration, statistic Norway, and EU joint research institute (travel habit survey of citizens, bus emission, data of diesel/gasoline used, and data of other basic factors). The action plan aims to provide eMobility service using individual resources provided by the business in ensuring that the TTC and eMobility applications are aligned and data is integrated via REST/HTTP over Transmission Control Protocol (TCP)/Internet Protocol (IP) when citizens interacts with the e-Mobility operations. The plan, resource, and capability for e-Mobility operations can be effectively implemented by enterprises using common vocabulary and semantics, open data, and open source components in order to enable communities to remain/become vendor independent.

4.2.7. Context Architecture

Lastly, the context layer captures the KPIs to be achieved by the city which comprises of percentage of transportation mode to EV mode, reducing CO2/NO emission, increasing annual return on investment, increasing the amount of renewable energy traded, decrease in simple payback time and also creation of new jobs.

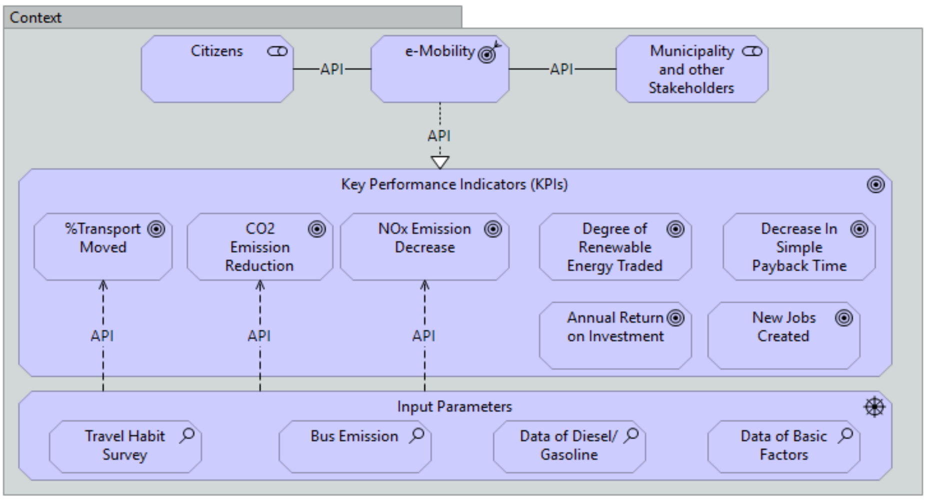

Figure 10. Meta-model for context integration for e-Mobility service

The information on each KPI are generated from different systems aligned and data integrated to the TTP backend application and eMobility application connected to statistics Norway, smart city information system, and data from EU research institute that aggregates, analyses, processes and use push and publish methods to publish data on the KPIs input parameters. The requirements or interests of stakeholders and citizens are gathered using open-source open data support platforms and accessed by citizens via APIs on their devices and web portals for decision making.

5. Discussion and Implications

5.1. Discussion

Changes in global urbanization has resulted in population increase. At the same time, recent technological advances are facilitating the digitally transformation of cities into smart cities putting immense pressure on stakeholders and disrupting urban services. Cities are facing disruption from new technologies; thus, municipalities are poised to adapt and change their current services that are provided to their citizens. This has resulted to system alignment and data integration issues in smart cities. Respectively, system alignment relates to the autonomy and joined coexistence, whereas data integration refers more to the concepts of coordination of multiple data sources (real-time, online, and historical data) (Anthony and Petersen, 2019). Similarly, in cities heterogenous systems typically do not integrate, but in order to integrate data generated to provide digital services to citizens and stakeholders the systems that generates and exchange data need to be aligned (Costin and Eastman, 2019). Thus, there is need to facilitate data exchanges of these systems to achieve alignment and integration of these systems (Vakali *et al.*, 2014).

According to Heaton and Parlikad (2019) creating alignment between city asset and services has added benefits as it allows owners of city services and data to have a holistic understanding of their assets deployed to provide services to multiple stakeholders, thus enabling data owners to manage, operate, and maintain their data. This is particularly important when cities data assets have public and private owners. Likewise, data integration has been an important issue for digital transformation of cities in order to improve digital services. The data integration in urban environment aims to improve data access and usage in making decisions (Nemirovski *et al.*, 2013). Data integration helps to connect different data sources used by virtual enterprises in cities that collaborate to provide digital services (Janssen and Cresswell, 2005). Overall, data integration provides access to real time information to citizens and stakeholders in smart cities (Javidroozi *et al.*, 2015; Vakali *et al*., 2014).

Thus, system alignment and data integration in digital transformation of cities forms a tightly coupled and interoperable eco-system where system components and data are interdependent and works seamlessly to provide digital services to citizens and stakeholders. The systems and data sources are connected via communication network, APIs, etc., and can interact and exchange services while locally maintaining their own logic of operation. Hence, in this study, smart cities are explored as an enterprise having a pre-defined set of goals and composed of several inter-related entities. Therefore, this study adopts enterprise architecture to helps cities analyze, plan, design, and implement their actions using ICT to achieve satisfactory development and deployment of their strategies (Tanaka *et al*., 2018).

The EA framework presented in this study helps to clearly define areas that need to be addressed and offers a classification in which these areas are to be addressed (Mamkaitis *et al*., 2016). The EA framework (see Figure 2) facilitates digital transformation of e-Mobility services to address issues such as integration and alignment faced during digital transformation (see Figure 3). As recommended by Sochor *et al.* (2016), the architecture facilitates the integration of existing transport providers and aligns transport solutions into a one stop, subscription-based e-Mobility service. Findings from this study are consistent with results from O'Brien, (2018) who suggested that EA aids business process via sharing and reuse of functional components, and through standardization of infrastructure and technologies. EA improves productivity across smart city service by integrating data sources. According to O'Brien (2018) EA provides a well-developed systematic method that aligns institution and their usage of IT and provides alignment across systems for effectively introduce digital transformations.

Findings from this study is also similar to results from Hämäläinen (2020), where the author developed a framework for digital transformation of Helsinki in becoming a smart city. The study is grounded on four dimensions (strategy, technology, governance, and stakeholders) which are required for to help implement smart city initiatives. Analogous to this current study the works from Hämäläinen (2020) considered the stakeholder and data perspectives but did not examine system alignment and data integration in digital transformation of cities. Similar to this study, our findings are analogous to results from Xue *et al.* (2019) where the authors employed EA to achieve a smart transportation based on integrated data to support decision making, however the system alignment involved for smart transportation is not well addressed.

5.2.Research Implications

The plethora of the data produced by system components such as IoT devices, sensors, metering devices, online sources, social media in cities are increasing. The systems are the infrastructure that forms the backbone of smart cities whereas data is the pillar that supports digital transformation of city in becoming smarter (Kong and Woods, 2018). However, the use of this data is hindered by issues, such as difficulty of integrating these available data from different isolated system (Gao et al., 2014). Therefore, this study contributes to the body of knowledge by developing an EA framework for aligning systems and integrating data for digital transformation of cities. EA approach is employed to address system alignment and data integration in digital transformation of cities similar to prior studies (Hjort-Madsen, 2006; Chen *et al*., 2008), which adopted EA to address interoperability issues.

The presented EA framework helps to guide business processes and the associated deployed IS towards a common goal by integrating business, information, data, and technology. Also, the EA framework can be employed to address integration issues faced by practitioners in urban sector. Respectively, findings from the e-mobility case reveal that the use of EA is a promising approach to achieve system alignment and data integration in digital transformation of cities. Besides, the EA framework can be adopted to linking up, integrate and align separated and isolated systems in achieving greater leverage of data in a transparent way to provide seamless, timely, and accurate information for citizens decision making.

5.3.Practical and Social Implications

Over the years the impacts of digitalization in urban environment have significantly changed rendering many business models obsolete. Hence, digitalization has become increasingly vital for cities seeking to grow and achieve sustainable development. Furthermore, the existence of isolated, overlapping, highly fragmented, and unrelated data sources from heterogenous systems has resulted to an isolated islands of silos systems in cities (Hjort-Madsen, 2006). However, so far, little empirical evidence exists on system alignment and data integration in digital transformation of cities. Achieving data integration and system alignment requires more than just using a common technical standard for different systems. Addressing data integration and system alignment means transforming urban processes to offer interoperable and seamless digital services (Hjort-Madsen, 2006).

However, to date fewer studies have explored the digitalization of cities. Also, issues related to system alignment and data integration needed for successful digitalization in making cities smart are still largely unexplored. To address these gaps, this current study contributes by employing EA for digital transformation to address system alignment and data integration in digital transformation of cities. Besides, findings from this research depicts a practical case (see Figure 3) that can be useful for researchers and practitioners by providing a detailed view of digital transformation for sustainable e-Mobility. The presented architecture can be utilized as a guide to help urban developers and designers in deploying sustainable transport policies for smart cities. This architecture can support e-Mobility providers of EVs to design and develop new business models. Findings from this study discuss how to seize the opportunity of EA and digital transformations in order to achieve a sustainable smart city.

6. Conclusions

Many cities are facing growth as people migrate from rural areas looking for better lives. Consequently, cities' services are digitally transformed to provide scalable services to citizens. But, are faced with challenge in becoming smart cities due to alignment and integration of systems and data sources utilized by virtual enterprises and stakeholders in urban environment. The alignment, integration, and co-operation of different stakeholders and data needed to implement, maximize, and manage the value of digital transformation is unprecedented. Although, the need for such alignment and integration is complicated due to heterogeneous technological solutions from providers such as IBM, Oracle, Cisco, Siemens, etc. deployed in cities (Kong and Woods, 2018). Hence, there is need for an approach that enables system alignment and data integration that can be synergically deployed to different sectors relevant to city development, e.g., transportation, energy, etc. in order to achieve pioneering solutions at district and urban level.

Enterprise architecture can be employed to support the transformation of smart cities to establish the current and the anticipated state of the city. Accordingly, this study presents an architecture to support alignment and integration among different components (IT, data, enterprises) operating in a city allowing stakeholders to collaborate in exchanging data via different systems for sharing resources and providing seamless services. An e-Mobility case is modelled in ArchiMate language based on data collected from interviews and discussion to depict the relevance of the architecture in exposing cross platform, and/or cross-domain utilizing different data sources from different partners to enable integrated resource sharing in aligning multiple systems. The limitation of this study is based on the fact presently, data security, privacy, risk assessment and governance are not fully addressed in the current developed architecture. Secondly, that data was collected from only 5 interviewees from a single case study in Norway. Thirdly, stakeholders and data perspective in the developed EA was not modelled. Future work will be directed to include data security, privacy, risk assessment and governance. Also, a multi-case study from two or more organizations will be conducted to further validate the architecture with real cases from other smart city dimensions. Additionally, in future the stakeholders and data perspective will be fully modeled connecting to the horizonal layers in the EA framework.

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