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Applying Enterprise Architecture for Digital Transformation of Electro Mobility towards Sustainable Transportation

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ABSTRACT

Electro Mobility (eMobility) involves deploying Information and Communication Technologies (ICT) and electric technologies in vehicles to enable electric propulsion of vehicles referred to as Electric Vehicles (EVs). EVs are key infrastructure for achieving a sustainable energy future since EV usage can support in achieving CO_2 reduction. However, the deployment of EVs for eMobility is highly dependent on data integration of mobility solutions from different stakeholders involved in urban transportation. Respectively, data integration from different mobility services will result to cost reduction and create valued added services to citizens. Therefore, there is need to achieve data integration not only for physical systems but for all domains in providing mobility related services that can be synergically applied to citizens and stakeholders in order to develop innovative solutions at district and urban level. Therefore, this study adopts Enterprise Architecture (EA) for digital transformations of eMobility services for sustainable transportation. Action research methodology was employed and secondary data from the literature was presented in the industrial data space reference architecture to initially validate digital transformation of electro mobility. Findings from this study reveal that EA support digital transformation of eMobility in managing data integration to support cities to implement sustainable transportation services.

CCS CONCEPTS

•Information systems →Information systems applications; •Information storage systems →Storage architectures •Social and professional topics →Computing / technology policy

KEYWORDS

Energy informatics; Electric vehicles; eMobility; Data integration; Digital transformation; Enterprise architecture; Sustainable transportation.

ACM Reference format:

1 INTRODUCTION

Research and development related to sustainability issues has increased across multiple areas. Also, for Information Systems (IS) research domain, Watson et al. [1] called for the research related to energy informatics to address environmental sustainability. Thus, IS community can contribute to a sustainable future by exploiting the potential of IS within the field of transportation in cities [2, 3]. Urban services are faced with disruption from cutting-edge technologies that drives municipalities to change urban transport operations to be able to provide mobility services to citizens.

Digital transformation of cities changes the way residents commute. Hence, cities are presently transforming their transport services by adopting Electro Mobility (eMobility). In 2011 the European Commission presented its transportation strategy for 2050 which aims to achieve low-emission mobility by reducing combustion engine vehicles in cities by 2050 [4]. Likewise, the European Union (EU) has committed to decrease Europe’s greenhouse gas emissions by 20 percent in 2020, and by 80 to 95 percent in 2050, as compared to the 1990 level.

To achieve this goal non-renewable energy sources such as coal are likely to be substituted by renewable energy sources such as use of electro mobility or eMobility [5]. Thus, to achieve a decarbonized and sustainable energy system facilitated by IS, eMobility is proposed to play a vital role, where eMobility is the use of electric propulsion for daily transportation of people and goods [6]. Currently, sustainable urban transportation is considered a crucial element in making cities smarter and eMobility is seen as one of the approaches that promotes energy efficiency of transportation infrastructures while decreasing carbon emission [7].

Vehicles which are propelled by electricity as their main energy source are referred to as Electric Vehicles (EVs). This also consist of vehicles which actively recharge their battery [8]. Thus, an EV is a vehicle powered by an electric motor using energy from a portable energy storage device (such as rechargeable storage battery or from an external energy source off the vehicle such as a public or residential electric service), to be used on public roads, streets, or highways [9].

As the demand for low-carbon sustainable transport solutions is increasing, the electrification of vehicles termed EVs is becoming widely used in cities across the world. This is because EVs have improved energy efficiency than combustion engines

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which produces exhaust emissions. In urban settlements, such as cities, EVs can have a significant positive impact on the environment, particularly if the batteries are recharged from renewable energy sources [10]. As the transportation sector is one of the key contributors to Greenhouse Gasses (GHG), there have been several policies and regulations to decrease their negative effects [11].

eMobility “supported by ICT” referred to Digital Transformation (DT) could contribute to achieve sustainable transportation. DT embrace ICT systems such as analytical systems, virtualization, and mobility are integrated with back-end IS to provide a holistic view of the digital eMobility system [12]. DT provides a feasible way to attain sustainable transport and has developed as an emergent concept that entails eMobility distribution approach in which a citizen’s transportation requirements are managed over a single platform offered by a single service provider. Accordingly, it combines all available EVs transport forms into a seamless journey chains, with reservation and payments managed together for the trip [13].

In order to effectively deploy eMobility and extent other services to citizens [14], there is need to achieve data integration which is the ability of two or more components or systems to connect and exchange information to be use [15]. Additionally, integration is the ability of two systems to connect and interact with one another and/or utilize one another’s functionality. In the context of digital transformation for eMobility, integration refers to the exchange of information and services between different partners systems to provide eMobility services to citizens. Therefore, this study addresses the following research question;

How to effectively deploy eMobility and extent other services to citizens in achieving data integration?

To provide answer to the research question in addressing data integration, this study contributes by presenting a reference architecture for digital transformation of eMobility services to support data integration, implementation, and migration [16]. In electricity sector a similar architecture Smart Grid Architecture Model (SGAM) has been utilized by prior studies [6, 15, 17] to investigate eMobility services. But, SGAM is more aligned to energy management in smart grid and less concerned about data integration. Therefore, this study employs Enterprise Architecture (EA) for digital transformation of eMobility services similar to prior study [5, 10, 15, 18] who employed EA for the interaction of EV with the energy grid for interoperability and information flow. EA provides blueprint for the deployment of future systems components to identify gaps for improvement in current systems [18].

Moreover, EA is utilized to bridge the gap between Information Technology (IT) and business [15] and can be adopted for modelling information flows for sustainable urbanization. The remainder of this article is organized as follows. Section 2 is literature review, and then section 3 is the methodology. Findings is presented in section 4. Section 5 is the discussions and section 6 is the conclusion.

2 LITERATURE REVIEW

This section discusses on the overview of EVs and eMobility, digital transformation of eMobility, and overview of enterprise architecture.

2.1 Overview of Electric Vehicle

The first electric vehicle was invented in early 1800s before the rise of gasoline driven vehicles. In 1900 nearly one third of all vehicles in the United States (US) were electric, because EVs are clean, silent, and easier to operate [8]. Yet, EVs are faced with issues which includes being slower than gasoline driven vehicles and are lower battery range of 40-65 kilometers in its inception [8]. Also, there is need to regularly recharged batteries which took longer time and there were issues of non-existent charging infrastructure. Besides, the buying costs of an EV is higher than a similar sized fossil fuel based vehicle, although maintenance costs is estimated to be lower for EVs and incentives are provided to purchase an EV [5]. As such driving was only possible in districts with available charging facilities [5]. All these issues lead to decline of EV in the year 1920. But, EVs usage was triggered in 1990s due to environmental need to reduce CO_2 emission from vehicles [8]. EVs are not limited to cars, but also consist of motorcycles, vans, scooters, buses, and trucks propelled by an energy source.

Currently, there are four categories of EVs as discussed below; *Hybrid Electric Vehicle (HEV)* which uses two or more different energy sources in order to move. In this EV the electricity only provides support and is not the main engine. The battery is recharged by the deceleration of the electric based engine. Toyota Prius is an example of HEV [16].

Plugin Hybrid Electric Vehicle (PHEV) is a type of EV that is similar to the HEV but employs the option to recharge the battery by plugging the EV into the electricity grid. This aids the vehicle to move a limited range without the use of internal combustion engine. Chevrolet Volt is an example of PHEV [16].

Extended Range Electric Vehicle (EREV) is a type of EV that is propelled based on a full electric engine, supported by an auxiliary fuel engine that recharge the battery to extend the range. Opel Ampera is an example of EREV [16].

Battery Electric Vehicle or Full Electric Vehicle (FEV) is a type of EV that is powered by a full electric engine and does not use any combustion fuel engine and does not have an auxiliary on-board power. The Nissan Leaf or the Tesla Model S are examples of FEV [16].

Furthermore, a typical example of an EV charging infrastructure is shown in Figure 1 comprising the car fuel tank and battery. Besides, as seen in Figure 1 “CS” represents charge socket, “SM” is the sub meter and “M” is meter connected to the smart grid. Thus, the smart meter registers the aggregated energy usage from the charge socket outlets and meters via cable & plug deployed to calibrate electricity readings per charge session. Also, the sub meter is connected using a communication protocol such as Open Charge Point Protocol (OCPP) which offers a protocol that makes integration and interoperability possible between a charging station and eMobility central system. It also allows charging stations and central systems from diverse EV vendors to easily connect with each other.

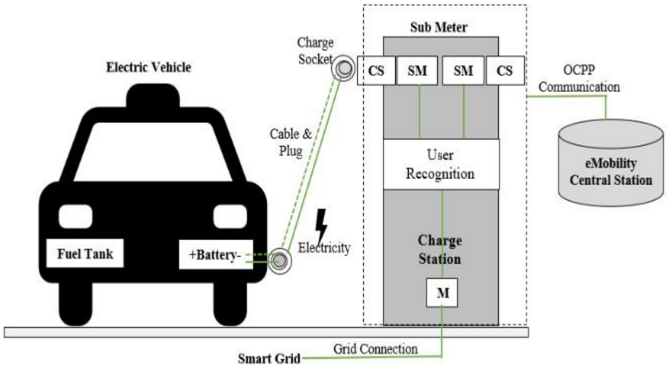

Figure 1: Example of EV and charging station [16]

2.2. Overview of eMobility Business Actors and Infrastructures

This sub-section discusses the interaction of business actors and infrastructures for eMobility services. Thus, Figure 2 illustrates the high level overview of business actors and infrastructures involved in eMobility service.

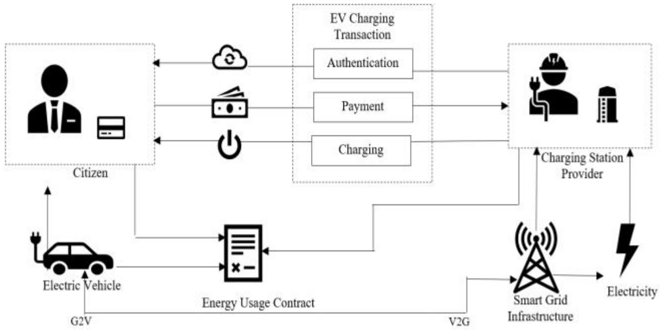

Figure 2: Overview of business actors and infrastructures involved in eMobility

Figure 2 depicts an overview of eMobility service where the citizen reserves an EV and then proceeds to charge the vehicle. The charging service provider is connected to the digital business to provide charging stations infrastructure [13]. By means of the charging station energy is delivered to the EV as Grid-to-Vehicle (G2V) and back to the grid as Vehicle-to-Grid (V2G). The transmission of energy is a part of the EV charge transaction [10]. Nevertheless, before this part of the EV charge transaction starts, the citizen needs to be authenticated and mode of payment needs to be selected based on a specified transaction contract. Since the EV may be plugged-in to charge and unplugged several times a day, the charging procedure has to be user-friendly and simple [10].

To make eMobility more flexible, in-vehicle digital services should be provided through third parties integration which offer additional services, e.g. navigation system updates, weather condition, and entertainment [10]. Further, EV may provide electricity to the smart grid via vehicle-to-grid (V2G) to supplement high demand of energy.

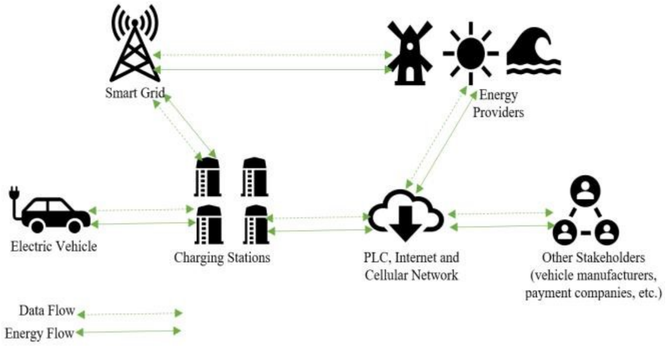

Figure 3: eMobility infrastructures for EV usage [8]

In urban environment eMobility infrastructure mainly comprises of EVs, charging stations, and the smart grid as seen in Figure 3. Likewise, other business actors which are not directly involved in the charging process such as the vehicle manufacturers, payment companies, etc. may be considered as part of the eMobility infrastructure since they manage billing, energy/data exchange, and other additional services [8]. The smart grid communicates with the vehicles through the charging station. The eMobility infrastructure allows a bi-directional data and energy flows where communication is transmitted through open standards, protocols, cellular network, Power-Line-Communication (PLC), and the Internet [13]. Thus, once an EV plugs into the charging station, the communication is transmitted through power-line and charging spot is connected to the smart grid for electricity delivery which communicates with the smart grid using PLC to a nearby aggregator station and then to the Internet or cellular network [8, 19].

2.3 Digital Transformation of eMobility

Over the decade, Digital Transformation (DT) has emerged as an important paradigm in IS research. DT involves changes taking place in industries and the society through deployment of digital technologies [20]. Some organizations see digital transformation as a medium to optimize business processes and reduce costs, while others view it as a prospect to design new value by providing services that do not exist [21]. Typically, digital technologies do not replace and displace existing components they rather enhance and digitize existing process transforming them into data sources and enabling innovations [22]. DT aims to provide significant changes through the combinations of computing, communication, information, and connectivity technologies [20].

Moreover, digital technology significantly accelerates business models, opening up new opportunities for structuring eMobility activities. Digitally supported organizations are enabled by ICT referred to as digital technologies, which increasingly offers enormous opportunities for growth. These novel digital technologies employ ICT systems such as mobility, analytical systems, and virtualization to provide a holistic view of digital enterprise [23]. Thus, cities are moving towards digital transformation as a means to achieve better services such as efficient energy, sustainable transportation, eMobility, etc.

eMobility is a broader concept that utilizes smart grid infrastructure and makes use of cellular network and Internet for data transfers with third party applications. eMobility comprises data and energy communication between EVs, charging station smart grid, etc. [18]. Therefore, DT in eMobility uses a digital interface to manage and source the availability of EV based services which meets the mobility needs of citizens [12]. DT provides new opportunities to enhance citizens' transportation choices and support improved efficiency regarding how eMobility services are provided.

DT deploys technology and new business models to provide municipalities with data to help manage city's transport networks and systems. It provides a digital interface to access and manage the provision of city's transport requirements [24]. DT aims to transform the way in which citizens choose to travel from one location to another by providing opportunity for decision makers to secure benefits for society [12]. To the best of our knowledge, there are fewer discussion on DT, which explores how cities employs digital technologies, to develop digital business model that helps to create more value for eMobility services.

2.4 Overview of Enterprise Architecture

An enterprise consists of multiple organizations working jointly to provide services that no single organization can provides alone. The concept of Enterprise Architecture (EA) was proposed by John Zachman in 1987 to decrease complexity of developing ISs [16]. Over the decade EA has become an established domain for business and IT system management. EA ideally aid stakeholders of organization to effectively communicate, document, plan, and design of business and IT related issues. For instance, EA provide decision support to stakeholders. EA promotes the belief that an institution as a complex system, can be improved or designed in an orderly fashion to better describe the fundamental structure of the enterprise [25]. It supports transformation by providing a holistic perspective of as-is as well as to-be processes and structures of the system. EA depicts the fundamental structure of a system and its components, the relationships, environment, and principles governing its design and evolution. It effectively and efficiently communicates and document the essence of IT and business components for stakeholders [18].

Furthermore, EA aids to plan, lead, design, control, and manage organizations, processes, and/or systems in present, transitionary, and future states, and the relationships among them. It describes an enterprise in terms of its structure, strategy, value streams, information flows, and physical instantiations as well as its transaction, and business models [18]. It also defines the technology, network infrastructure, and utility connections. EA, when fully designed, creates a holistic information base that efficiently describes an enterprise [25]. Thus, EA is deployed as frameworks which embodies the structure to model enterprise's IT and business components.

EA frameworks constitute the fundamental of EA approach and serves the purpose of making the complexities of real world manageable and understandable to stakeholders [26]. Currently, there are different EA frameworks that exist, such as the Zachman framework, first published in 1987 is one of the earlier frameworks proposed for EA. Another leading EA framework is The Open Group Architecture Framework (TOGAF), which was developed as a methodology for deployment of technical architectures but later shifted its emphasis of EA over the years. According to Riege and Aier [27] EA is widely accepted as a method to manage transformations and to support business/IT alignment. Therefore, EA framework is employed in this study for digital transformation of eMobility services.

3 METHODOLOGY

This study adopts action research approach. Action research is literally composed of action and research or rephrased as practice and theory [31], where action involving real world scenarios of improving practice research relates to development of new knowledge [32]. Moreover, actions taken should be informed and guided by theoretical framework appropriate to the research context to be explored [33]. Action research has become increasingly prominent among academicians in information systems domain as an adopted paradigm employed to validity research [32].

Action research is concerned with elaborating and developing theory from practice as it produces insights regarding understanding and confirmation of models in relation to what practitioners or end users do and what theories are employed when faced with the need to act [33]. In action research the process of exploration is employed, and findings can either be replicable or demonstrable through analysis, argument, or model. Action research approach has been adopted by prior electric mobility studies [34, 35], hence this study opted for this approach where secondary data (research) is collected from the literature to practically verify IDS-RAM as an EA framework (action) for digital transformation of eMobility services.

3.1 Design Method

The enterprise architecture is applied for digital transformation of eMobility services. Accordingly, the industrial data space reference architecture model (IDS-RAM) is adopted as an EA framework for digital transformation of eMobility for sustainable urbanization. IDS-RAM was proposed by Otto et al. [28] as a virtual data space that leverage existing technologies and standards, governance models for data economy, in facilitating the standardized and secure exchange and linking of data in trusted enterprise ecosystem. Thus, IDS-RAM provides the foundation for achieving smart services and innovative cross-industrial operation, while concurrently ensuring that data sovereignty is deployed for data owners [28].

It relates to the business entity's ability of being completely self-determined with regards to data, hence data management is an essential characteristic of the industrial data space. In addition, IDS-RAM is based on a reference architecture model which provides trusted and secure data exchange in enterprise ecosystems [28]. IDS-RAM aims at setting a universal standard by getting the needed requirements from several stakeholders. The IDS-RAM framework comprises of business, functional, process, information, and system layers. It also comprises of three perspectives which are security, certification, and governance as seen in Figure 4.

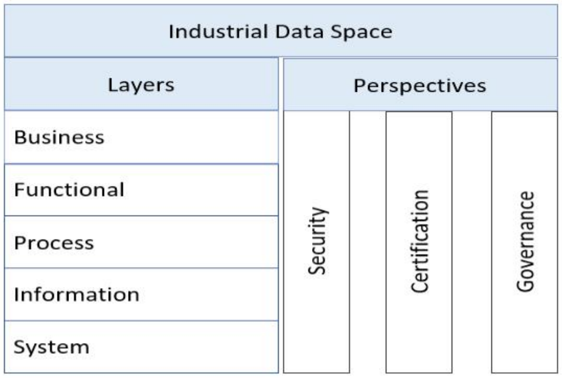

Figure 4: IDS-RAM framework [28]

3.2 IDS-RAM Layers Components

The layer components of IDS-RAM are discussed below; *Business layer* categorizes and specifies the different roles of stakeholders involved in providing digital service. It also stipulates the main interactions and activities link to each stakeholders' roles and vision [28]. The business layer contributes to the development of business models that can be utilized by stakeholders [15]. Moreover, the business layer identifies important activities and interactions linked to other components in the business eco-system [16]. It presents a business abstract description of IT and business components as a blueprint that can be used to verify the technical requirements to assess whether all essential interfaces for business operations are functional [5], or if the information required for deploying the business process is available [28]. This layer provides a corporate viewpoint focusing on tactical and strategic goals, business services, and business processes as well as regulatory aspects [17]. It represents the business viewpoint on the information exchange in providing services [6].

Functional layer describes the practical requirements of digital system and specifies the main features to be derived from digital transformation [28]. The functional layer defines existing technologies and applications needed to provide services to end users [5]. Additionally, this layer includes IT-oriented, technological descriptions of general use case functions of business collaboration [17]. *Process layer* stipulates the interactions that occurs between the different components of the digital system by providing a dynamic view of business/IT eco-system [6]. The process layer comprises the roles of stakeholders introduced in the business layer in providing, exchanging, and publishing data and using data applications [28].

Information layer provides a conceptual view of linked data sources both static and the dynamic data constituents [6]. The information layer specifies which domain data is required to provide digital services to end users [5]. This layer establishes a central agreement shared by all stakeholders and components, to support data compatibility, integration, and interoperability [28]. The information layer presents information about data models to support the exchange of data to enable interface interoperability [17].

System layer comprise of hardware (physical devices such as metering devices, Internet of Things (IoT) sensors, etc.) [18], IT infrastructures, network infrastructure, and software concerned with real time data processing to support basic connectivity [10], configuration, and integration of the aforementioned components [6, 28]. The layer also presents procedures and protocols for data generation and collection between IT components [17]. It further describes the communication technologies and protocols for the interoperable exchange of data from physical objects supporting digital functions [6, 15].

3.3 IDS-RAM Perspectives Components

Directly associated to the five layers of are three cross-sectional perspectives discussed below;

The first perspective component is the *security perspective* which aims to ensure and achieve secured data for establishing trust among stakeholders and system that exchange data to be utilized by applications to provide digital services [28]. Thus, security component provides means to identify stakeholders, protect data communication, and exchange between the use of data and after it has been sent [13]. Thus, this component in IDS-RAM enforces mandatory identity and access management for identification (claiming an identity), authentication (verifying an identity), and authorization (granting access based on an identity) [28].

Next is *certification* component which aims to ensure high degree of security regarding the confidentiality, integrity [13], and availability of data exchanged in digital services by deploying a consistent accreditation and evaluation procedure for all business stakeholder and IT components to improve security and trust within the eco-system for improved business interoperability [28].

Lastly, is *governance* component which defines the roles, processes, and functions of the digital service from a compliance and governance point of view [28]. It thereby outlines the requirements to be achieved in the business ecosystem to attain a reliable and secure business interoperability [16]. It particularly helps the stakeholder involved in providing services to outline agreements and rules for compliant collaboration [18]. In more detail, the component supports governance by providing an infrastructure for corporate interoperability data exchange, and adoption of new digital business models [28]. It also helps to establish trustworthy relationships between data consumers, data owners, and data providers acting as a trustee for mediation between stakeholders facilitating negotiation of business contracts and agreements to improve transparency and traceability of data use and data exchange [18]. Lastly, it allows public and private data exchange, considering individual requirements of stakeholders by proving a decentralized business model that does not require a central authority [28].

4 FINDINGS

This section demonstrates the application of IDS-RAM as an EA framework for digital transformation of eMobility services as seen in Figure 5. The eMobility scenario shown in Figure 5 only considers the IDS-RAM layers in this study, thus the perspective components of IDS-RAM are not considered in this study.

Data integration in eMobility service is important because the integration of data from different services can be employed to provide information on battery health recommendations, EV fleet management for EV company and other charging services such reservation, charging station status, dynamic prices and green charging availability [13]. Therefore, as seen in Figure 5 in reference to the *system layer* real time data is collected from surveillance cameras, traffic sensors, EVs, e-charging station via communication means such as Wi-Fi, Bluetooth, Zigbee [5].

The system layer also connects to the smart grid for V2G and G2V connection of energy and data and the distributed ledger technology payment gateway which process e-charging payment [8]. Next is the *information layer* which comprises of several data sources which are integrated to provide different digital services to enhance eMobility operations [6]. The data sources consist of EV operators, EV sharing dealer, EV sharing customers, EV car, citizen/billing, charging station location, and vehicle energy status database [4].

In the *process layer*, the eMobility digital service deploys Application Programming Interfaces (API) as suggested by Anthony Jnr et al. [10] to provide application access to several data sources for fully functional eMobility operations. The APIs comprises of real time location, EV fleet data, EV car data, historical data, e-payment, energy usage data, and energy saved data [10].

Besides, the API uses Representational state transfer (REST) call to access data in JavaScript Object Notation (JSON) and Extensible Markup Language (XML) format via POST/GET calls via Structured Query Language (SQL) query for web service. The aforementioned APIs aids to provide data for geographic information and services data for EV map routing to be used by the eMobility application that integrates, aggregates, publish EV charging data. Which analyses e-charging data request to manages e-charging payment via distributed ledger data which presents all integrated information into a data analytics user dashboard for decision making [4].

The *functional layer* employs “Push” and “Pull” method to provide information to stakeholders/citizens such as the EV rental company that sends code, pull geographic information, and EV services info, city transport and infrastructure company that pull available EV location and nearest bus route to reach EV [13]. It also comprises of the municipality and energy company that pull available e-charging stations type, electricity type, and e-charging fees, and lastly the EV rental and payment company that push billing information for e-charging, kilometer driven, and recommends EV parking spot [5].

Finally, the *business layer* entails enterprises that collaborates to provide digital services such as eMobility sharing service, e-charging stations service, and payment notification service for the complete eMobility digital services for sustainable transportation in municipalities [7]. The citizens utilize these digital services as seen in Figure 5 by using eMobility application preferability from a mobile device to search for available EV and the system retrieves available EV information to the citizen based on his/her mobility preferences and inputs.

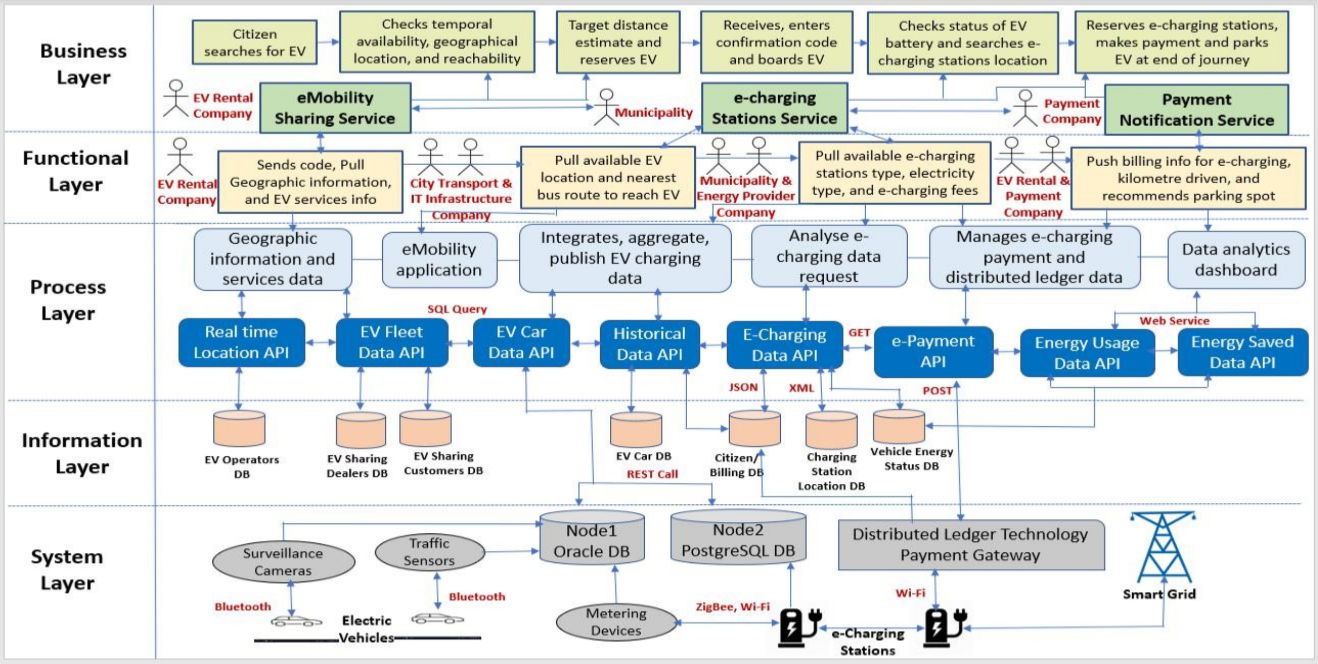

Figure 5: Application of EA for digital transformation of eMobility services

The EV user then reviews the recommended travel plans and can either starts his/her travel journey based on the inputs or adjust the input and re-plan the trip or stop interaction with the eMobility application. This is done by checking temporal availability, geographical location, and reachability. As well as target distance estimate and reserves EV [8]. Upon the selection of a mobility plan by the citizen, the eMobility application performs seamless eMobility functionalities (for example showing of e-charging station on the map based on cheapest or greenness factors with percentage of renewable energy, battery health status, parking stations, best route, and then sends back a confirmation to the EV user [8].

Next, the citizen receives and enters confirmation code and boards EV, then he/she checks status of EV battery and searches e-charging stations location and lastly reserves e-charging stations, makes payment and parks EV at end of journey [5]. Additionally, Figure 6 depicts the sequence diagram of how the citizen interacts with the eMobility application which sends and receives information from the eMobility service center [5].

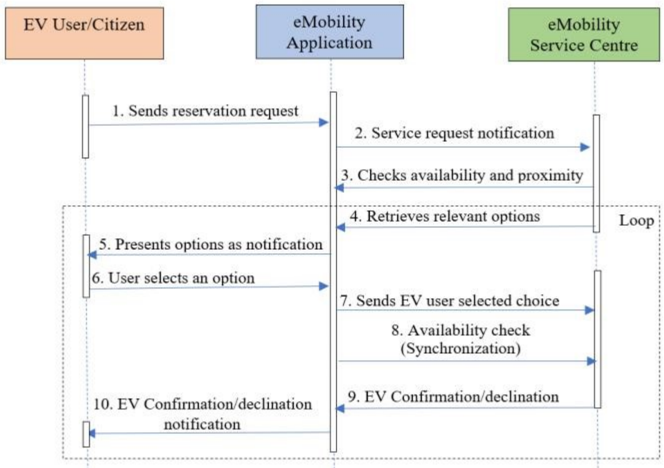

Figure 6: Sequence diagram for EV reservation adapted from [7]

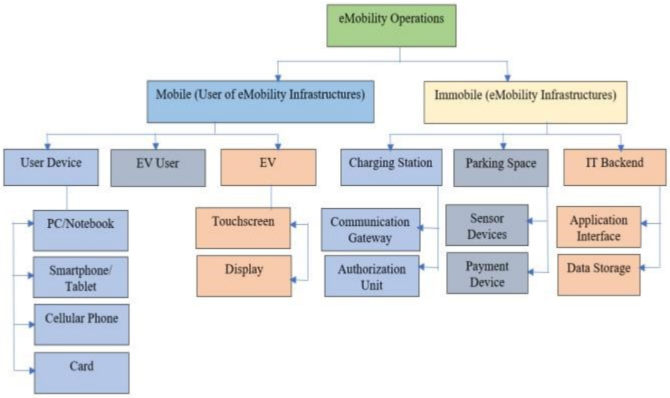

Figure 7: Summarized eMobility operations adapted from [15]

Furthermore, Figure 7 illustrates the main components for eMobility operations which comprise of mobile (user of eMobility infrastructures) and immobile (eMobility infrastructures). Also, as seen in Figure 7 other infrastructures needed to support eMobility operation includes the citizens device, the EV user, the EV, charging station, parking space, and lastly IT backend for data integration [7].

5 DISCUSSION

The need for mobility services to become environmentally friendly [29, 30], has increased the rise of digital transformation which fundamental transformed how transportation systems work in urban environment [13, 36]. Thus, DT is commonly regarded as the next paradigm change in urban transportation as it offers viable, flexible, easy, reduced cost, and other mobility related options to citizens, such as public transport routes, vehicle-sharing, vehicle leasing, traffic status, and road use. From the citizens perspective, DT aids planning, booking, payment, as well as seamlessly integrating all transport systems and means, using real-time data [11]. Although, DT for eMobility is faces with several challenges, ranging from network, requirements, communication protocols, interfaces, data integration, etc. [8, 37].

Hence, data integration is a prerequisite for DT of eMobility services because transport service providers need to have access to real-time traffic and transport data as shown in Figure 5. Enterprise architecture is suggested in this study to support data integration of digital transformation of eMobility services as seen in Figure 5. EA is proposed as an approach to address data integration issues because EA provides the capability to support changes that drive digital enablement and business innovation. EA decreases business complexity via sharing and reuse of functional components, and through standardization of infrastructure and technologies. Findings from O'Brien [25] suggested that EA improves the quality and performance of business processes and improves productivity across enterprise by integrating and unifying data linkages.

According to O'Brien [25] EA provides a well-developed systematic method to align enterprise and their usage of IT and provides alignment across business processes. It is an effective medium to introduce digital transformations. Researchers such as Anthony et al. [18] argued that the blueprints designed by EA provide a basis for modelling, planning, and optimizing the performance organization operations.

Findings from this study provides managerial and theoretical implications suggesting that EA aids stakeholder in eMobility services understand their current composition, incurred costs, utility employed, and sources of value generation. Moreover, the findings reveal that EA decreases complexity by representing the technical standards and functional principles for guiding business solution technology and design choices.

Besides, the findings suggest that EA promotes data integration and consistency across process, application, information, and infrastructure for optimal business performance. Additionally, findings from the modelled case (see Figure 5) provides implications suggesting that historical, online, and real-time data are important and need to be integrated for managing transportation logistics [11]. The application of EA to digital transformation provide implication for municipalities, transport companies and energy providers with detailed information about energy flows and transport services in cities.

As seen in Figure 5 practical implications from this research entails provision of mobility related data which are aggregated, analyzed, integrated, and used via eMobility platform. Furthermore, these data can be used to support decisions in terms of mobility planning and investment towards EV. The application of EA as seen in Figure 5 provides an ecosystem of IT and business components, processes and capabilities which provides eMobility functions and services enabling sustainable transportation. It aggregates data and control from a variety of sources and “things” (i.e., metering devices and sensors), to present information to citizens and stakeholders.

Besides, the integrated data via APIs enables business intelligence by providing access to open data and functionalities to support seamless integration of third-party open data to support the development of dashboards and applications for users (e.g., citizens, transport companies, city managers, etc.) by exploiting data collected. Moreover, the data collected from different heterogeneous sources provide an opportunity to assess the eMobility operations on different scales in municipalities. Hence, the integrated data is expected to catalyze and improve sustainable transport improvements and realizations, thus helping municipalities in developing innovative energy services for cities and beyond.

6 CONCLUSION

This study adopted the industrial data space reference architecture model (IDS-RAM) as an enterprise architecture framework for addressing data integration of digital transformation of eMobility services for sustainable transportation. The use of EA for digital transformation for eMobility application aids to also integrate and provide information on the EV status, location, usage price, charge type, and current booking list (see Figure 6-7). Moreover, via the eMobility application integrated and processed data from the EV data can be used to notify and guide EV user on the current EV battery charge threshold and attainable mileage.

Therefore, digitalization of eMobility services via EA provides an eco-system where EV users can request for additional information like current EV position, recharge preferences/time, battery status, and etc. Besides, digital transformation or eMobility services autonomously process citizens request, calculates the best available selections over the entire city context and provides the processed alternatives. The EV user can decide the most suitable option according to different criteria (such as closest to EV, EV with minimum queuing time, EV with least energy price) and waits for approval from the eMobility service center as described in Figure 6.

Furthermore, limitations from this study relates to the fact that the perspective components of the IDS-RAM EA perspectives components (security, certification, and governance) were not considered in the modelled scenario presented in Figure 5, only the layer components (business, functional, process, information, and system) were modelled. In addition, no real or primary eMobility data was collected and used to validate application of EA to address data integration of digital transformation, only secondary data from the literature was employed to model the eMobility case scenario in Figure 5. Therefore, future work will consider modelling the perspective components of the architecture and real data will also be used to validate EA application for digital transformation of eMobility services.

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