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Modelling Pervasive Platforms and Digital Services for Smart Urban Transformation Using an Enterprise Architecture Framework

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Abstract

Purpose

In smart cities pervasive systems are deployed by enterprises and stakeholders in municipalities to provide digital services to citizens. But cities are faced with the challenge of achieving system pluggability, mainly service integration due to numerous actors and systems needed for smart urban transformation. Hence, there is need to employ a comprehensive and holistic approach to help achieve service integration of pervasive platforms. Therefore, this study presents an Enterprise Architecture Framework (EAF) to support smart urban transformation.

Design/methodology/approach

In this study the design science research methodology is adopted based on a multi-case studies of two organizations and data is collected using semi-structured interview from an organizations and municipality in Norway to validate how service integration can be achieved by the developed EAF to address pluggability challenges faced in urban environment.

Findings

Findings suggest that the presented EAF provides the structure to manage changes and maintain urban transformation and aims to align the business with the underlying information systems from the perspective of the stakeholders. Additionally, findings from the case studies modelled in ArchiMate language depict how service integration of different pervasive platforms provide digital services for smart urban transformation.

Research limitations/implications

This research only employed semi-structured interviews to validate service integration of digital platforms, other identified dimensions of pluggability were not fully addressed in this study.

Practical implications

Findings from the case studies provides insights on how pervasive platforms can be integrated to achieve a pluggable digital service from different stakeholders and data sources in practice. The developed EAF presented in this study provide a model that supports collection and exchange of data from different data sources in smart urban environment to enable the provision and consumption of digital services.

Social implications

The developed EAF aids system pluggability of actors and systems in providing digital service such as smart urban transformation that contributes to sustainable use of electric mobility in cities.

Originality/value

As cities increasingly deploy pervasive platforms to support urban innovation, researchers are seeking to explore how these platforms shape urban transformation. Presently, prior studies do not offer important insights into pervasive platform management from urban perspective.

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Against this backdrop, this study employs the information systems perspective of digital platforms literature roots in software development and physical product development to depicts how the EAF can be employed to describe specific cases that integrate different pervasive platforms deployed by different stakeholders communicating to co-create collective digital services to citizens.

Keywords: Information systems; Smart cities; Pervasive platforms; Enterprise architecture framework; Ecosystem; ArchiMate modeling; System pluggability.

1. Introduction

Digital transformation and global urbanization are two current phenomena currently experienced in cities (Tanaka *et al.*, 2018). Sustainable urban development, maximizing economic opportunities, social inclusion, and lessening environmental damage are major issues that countries are currently faced with (Muñoz and Bolívar, 2019a). Transforming cities into smart cities aims to address these challenges (Rodríguez Bolívar, 2019). A smart city is an innovative city that effectively deploys Information and Communication Technology (ICT) and other resources to improve the efficiency of urban operations, economic competitiveness, quality of life, and services provided to citizens (Cortés-Cediel *et al.*, 2019; Anthony Jnr *et al.*, 2020). Smart cities ensure that the needs of present and future generations are addressed with respect to environmental, social, and economic, as well as technological and cultural aspects (Anthony *et al.*, 2020). Presently, cities around the world are increasingly implementing ICT for better administration (Muñoz and Bolívar, 2019b).

Accordingly, the provision of digital services to citizens in smart cities rely on a network of systems deployed by different partners (Zygiaris, 2013; Muñoz and Bolívar, 2019c). This connection of different systems forms a pervasive platform ecosystem (Usurelu and Pop, 2017; Zaramenskih, 2018). An important part of such ecosystems is the pluggability or tight integration of the underlying systems and IT infrastructures (e.g. third-party applications, open data sources, cloud services, remote servers, etc.) (Pittl and Bork, 2017). Thus, it is important for these pervasive systems to be pluggable in providing digital services for smart urban transformation (Rocha *et al.*, 2016; Aulkemeier *et al*., 2017). Furthermore, the systems and the overall smart city ecosystem should as far as possibly build on open standards, protocols, and data, to ensure contributions by many actors in a collaborative way without traditional barriers (Ahlers *et al.* 2019). Likewise, the increasing number of connected devices, sensors and metering devices provides real-time data that enables municipalities administration to gain insights into the needs of citizens (Berkel *et al.*, 2018; Tanaka *et al*., 2018). In current urban operations, an integrated model of all-pervasive systems linked to IT and business components is crucial. However, such an integrated model of the city's operations is mostly far from reality (Anthony Jnr *et al.*, 2020). To address this challenge, an approach is required that supports pluggability of pervasive systems within the city (Pittl and Bork, 2017; Mukti and Prambudia, 2018). At the moment, there is no standard approach for describing urban transformation across domain borders in a precise way (Pittl and Bork, 2017).

An Enterprise Architecture Framework (EAF) can be employed as an appropriate instrument for describing and simplifying such pervasive systems in smart city context (Jnr *et al.*, 2020). EAF integrate multiple views or perspectives to derive a comprehensive and coherent description of urban operations (Caetano *et al.*, 2017). However, existing EAF modeling tools such as 4EM, Semantic Object Model, business process modeling, integrated enterprise balancing, etc. have been previously employed in the literature (Lankhorst, 2004; Krogstie *et al.*, 2006; Plataniotis *et al.*, 2014; Krogstie *et al.*, 2018). These approaches use either detailed design languages or in informal models that inadequately provide definite visualization meaning that are easy to understand by non-experts (Pittl and Bork, 2017). Additionally, the aforementioned modeling tools where designed based on generality to help describe enterprises. This often leads to setbacks that impacts the collaboration of stakeholders involves in urban transformation (Pourzolfaghar *et al.*, 2019).

ArchiMate has lately become the standard EAF tool for describing and visualizing urban transformation encompassing different components, their dependencies, and their relations (Pittl and Bork, 2017). ArchiMate provides views on heterogeneous domains, such as stakeholders, business processes, application, data, and technological infrastructure (Antunes *et al.*, 2013; Bock and Frank, 2016). In this article, ArchiMate is employed as a modeling language as it aids in modeling urban transformation beyond the level of ICT experts and system developers to the level of municipality administrators and policy makers. Accordingly, this study aims to address the following research question:

RQ. How to support service integration of different pervasive platforms needed to provide digital services for smart urban transformation?

Therefore, the aim of the current study is to design a model-driven approach for achieving digital service which encompass service integration of software components as well as hardware components. Findings from this study provide a roadmap towards the development and integration of underlying systems to support the pluggability of the new and old infrastructures in urban environment. The remainder of the article is organized as follows: section 2 is the literature review. Section 3 presents the developed enterprise architecture framework and section 4 is the research methodology. Section 5 is the findings and section 6 is discussion and implications. Lastly, section 7 is conclusion.

2. Literature Review

2.1. Background of Smart Urban Transformation

Nowadays, cities across the world are being transformed in order to increase the efficiency, flexibility, and effectiveness of services provided to their citizens, support innovative solutions, develop more sustainable cities, and respond to global challenges. This transformation together with ICT deployment is termed as smart city or smart urban transformation (Bolívar, 2018). The vision of smart urban transformation aims to reduce the costs of urban services and maximize the return on investments, improve economic growth (Jnr, 2020b), transparency and competitiveness, as well as stakeholder involvement in cities (Hämäläinen, 2020). A city is smart when investments in social, human capital, and ICT infrastructure drives sustainable economic growth, while managing use of natural resources via participatory governance (Ahlers *et al.*, 2016; Anthony Jnr, 2020). Thus, in smart urban transformation cities try to address challenges caused by urbanization in improving the quality of services provided to residents. As seen in Figure 1 based on findings from the literature (Chourabi *et al.*, 2012; Antonova, 2018; Mukti and Prambudia, 2018; Sebastian *et al.*, 2018; Jayasena *et al.*, 2018) smart urban transformation is conceptualize into dimensions such as human, technology, built infrastructure, and institutions.

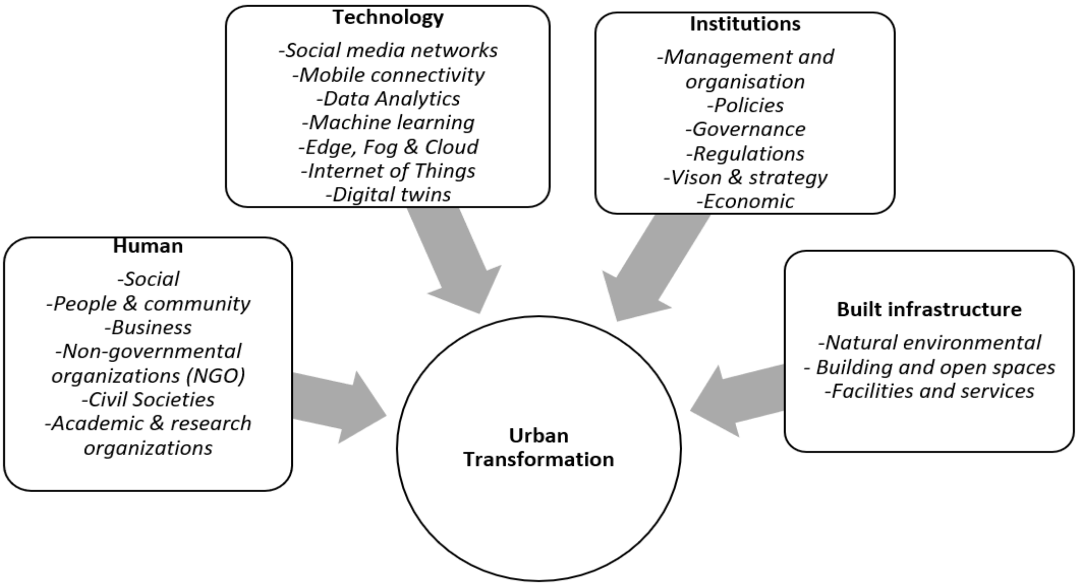

Figure 1. Dimension of smart urban transformation

Cities deploy innovative technologies in order to achieve a competitive and sustainable city (Mukti and Prambudia, 2018). Smart urban transformation involved a technology-intensive city that inter-connects people, data and systems (Jnr, 2020a). Accordingly, this current study is more aligned with the technology dimension as the scope of this article is positioned to designing a model-driven approach for achieving digital service which encompass the integration of software components as well as hardware components for smart urban transformation. Therefore, the technological aspect is explored in this study to efficiently manage digital services provided by municipalities.

2.2.Role of Digital Platforms for Smart Urban Transformation

Digitalization in urban environment occurs when systems are integrated supporting digital imperatives for municipalities to capture and create value (Zaramenskih, 2018). It is achieved by use of digital platforms to improve service efficiency and uncover new opportunities (El Hilali and El Manouar, 2018). Digital platforms are systems and infrastructures that provide access to computational capacity and data (Yovanof and Hazapis, 2009). They provide adapted digital services delivered based on specific end users' requirements. Also, digital platforms are data-driven systems (set of retro and digital applications, integrating several data sources) (Antonova, 2018). Digital platforms aim to enable the streamlining of urban processes and not only make urban services more accessible for citizens but also improve resource management and productivity within municipalities (Li *et al.*, 2016). By means of digital platforms, cities can optimize their services and performance.

Digital platforms support the digitalization of core city operations for smart urban transformation. Hence, urban transformation of city processes is achieved by providing citizens and stakeholders with appropriate digital services that would lessen transactional costs (Zaramenskih, 2018). Within the context of urban transformation, provision of digital services may be considered as a significant instrument for enhanced value creation in municipality (Hämäläinen, 2020). In municipalities digital platforms aid better provision of services or products using technologies such as data analytics, Internet of Things (IoT), Artificial Intelligence, cloud native applications, social media networks, a mobile connectivity, etc. (Tomičić Pupek *et al.*, 2019). Digital platforms support different actors in urban environment to share and exchange data in order to develop multifunctional digital services (Hämäläinen, 2020; Zaramenskih, 2018). Thus, traditional services are made more efficient with the use of digital systems and technologies referred to as digital platforms for the benefit of residents and businesses.

2.3.Theoretical Background Related to Digital Platforms

Digital platforms are becoming progressively important for cities for innovating urban business processes and services towards provision of services. These platforms act as a basis upon which cities can develop services (Rolland *et al.*, 2018). While the important of digital platforms are significant knowledge required for tactical and strategic implementation towards achieving pluggability of Information Systems (IS) is still an issue (Aulkemeier *et al*., 2017; Usurelu and Pop, 2017; Rocha *et al*., 2018). Although, research of digital platforms as regards to dependencies of deployed systems processes have been thoroughly examined in the literature (Sandberg *et al.* 2014, Rolland *et al.*, 2018).

To advance theory on pluggability of digital platforms in smart cities, this study draws on the theoretical concepts related to platforms as guided by Sambamurthy *et al.* (2003); Sandberg *et al.* (2014); Svahn *et al.* (2015); Rolland *et al.* (2018) to understand platform complexity faced by cities in managing digital platforms. By focusing on the transformative capabilities of digital platform in addressing pluggability issues enabling cities to achieve platform ecosystem in urban context. This study provides a city-centric perspective on the literature on digital platform ecosystems as suggested by Ghazawneh and Henfridsson (2013); de Reuver *et al.* (2018). The theory on digital platforms is multidisciplinary and encompasses the economics, information systems, and organizational perspectives (Gawer, 2014).

Figure 2 Theories on digital platforms

As summarized in Figure 2, the theories on digital platforms comprises of three diverse perspectives discussing what platform entails and how platforms evolve. One of the domains of digital platforms literature is grounded on information systems perspective with roots in software development and physical product development (Tiwana *et al.*, 2010; Gawer, 2014). As stated by Baldwin and Woodard (2009) IS perspective conceptualize digital platforms as technological architectures and as a set of stable components that supports evolvability and variety in a system by constraining the links among components (Baldwin and Woodard, 2009). Accordingly, digital platforms rely on modularization to ensure evolvability and maintain complexity in the design and management of technologies (Gawer, 2014). The IS perspective highlights that the technical design of digital platforms determines the evolvement and development of innovation (Tiwana *et al.*, 2010; Rolland *et al.*, 2018). In more recent research by Rolland *et al.* (2018), the IS perspective's notion has been expanded to a modularized layered architecture that captures different views for data, technologies, application, and services underlining the digital nature of platforms (Gawer, 2014). This modular layered approach creates the generative capability for numerous possibilities across layers in creating new forms of innovation (Gawer, 2014; Rolland *et al*., 2018).

The second stream of digital platform research originates from an economic perspective, which is less focused on the digital technologies but more aligned to business strategies, models, and value creation (Rolland *et al.*, 2018). In the economic perspective digital platforms are seen to comprise of markets that enable innovative forms of interaction between providers and consumers as well as disruptive traditional markets (Rochet and Tirole, 2003). The economic perspective also underlines the role of digital platform components in the form of digital services provided through software modules (apps) (Gawer, 2014). Hence, prior studies concerned with the economic perspective have investigated digital platforms in relation to digital phenomena such as sharing economy platforms, social media platforms and consumer-based platforms (Rolland *et al.*, 2018).

Furthermore, the organizational perspective of digital platforms does not view digital platforms as an exact technical architecture or a precise type of market (Wareham *et al.*, 2014), but instead highlights how diverse actors across a platform ecosystem coordinate and organize practices and initiatives to produce innovation (Gawer, 2014). Ciborra (1996) recommended that in changing or turbulent environments, organizations should act on volatility by building a moderately stable digital platform that would support creativeness in response to changing requirements and demands (Rolland *et al*., 2018). Therefore, the organizational perspective highlights stakeholders' practices in relation to the technical needs and markets established (Rolland *et al.,* 2018). The organizational perspective comprises of sociotechnical conceptualization of digital platforms as comprising of technological components (software and hardware) and related organizational standards and processes (de Reuver *et al.,* 2018).

Therefore, in deploying digital platforms within smart cities, it is imperative to go beyond traditional IS platforms such as enterprise systems and explore how digital platforms evolve within urban context through dynamic interaction and integration between the different systems (Henfridsson and Bygstad, 2013). Secondly, studies on digital platforms have mostly focused on how technologies can be employed as facilitators of innovation in creating new business models (de Reuver *et al.,* 2018). Prior studies have paid little attention to the challenges faced by cities in managing service integration of digital platforms in the context of ecosystems pluggability (Usurelu and Pop, 2017). Therefore, this study draws on information system perspective to understand how the pluggability of digital platforms can be achieved.

2.4.Theoretical Background of Pluggability and Proposition Development

Pluggability refers to a quality characteristic that defines the external feature of a service which supports its usage in a specific context (Rocha *et al.*, 2016). Pluggability can be considered as IS quality criteria that assess the ease of using new software services. It measures software services from end users and stakeholder's perspective (Usurelu and Pop, 2017). In smart urban context improving the pluggability of digital services means enabling the possibility to easily exchange, adopt, and upgrade digital services provided to citizens. The goal of pluggability is to achieve a fast and flexible provision of digital services in response to citizens requirements (Aulkemeier *et al*., 2017).

Over the years a few studies have explored pluggability in the literature, among these studies. Urošević *et al.* (2018) designed a flexible and configurable analytic model for urban IoT infrastructures to support seamless pluggable integration. The model also enables collection of data for analyzing behaviour of elderly people in support for smart urban vision. Aulkemeier *et al.* (2017) developed a novel system architecture to enhance the pluggability of digital commerce services. Their study suggested a paradigm shift from utilizing self-contained systems components to a platform-based services. Usurelu and Pop (2017) implemented a city dashboard platform that provides real-time data processing for smart cities. The dashboard is composed of a plugged data analytics functionality deployed based on a RESTful service. Aulkemeier *et al.* (2016) designed a pluggable service platform architecture to achieve agile and flexible service integration ecosystem and also extended additional services from third party providers. The authors aimed to achieve integration and interoperability towards enabling seamless coordination among various partners.

Rocha *et al.* (2016) developed a semantic model to support pluggability of heterogeneous intelligent devices in smart city environment. The model uses plug to integrate different components to achieve a fully functional and integrated smart city environment. Paspallis and Papadopoulos (2014) proposed a reconfigurable and pluggable architecture to support better resource utilization and context-aware heterogeneity. The architecture uses plugins for active mobile applications to enable middleware system. Mac-Vicar and Navón (2005) designed a web application based on a pluggable architecture to improve client's services and address extensibility issue. Their architecture is mainly grounded by Extensible Markup Language (XML) and Web Services plugins. Findings from the literature (Aulkemeier *et al*., 2016; Aulkemeier *et al.*, 2017) suggest that pluggability dimensions consists of integration, provisioning, adoption, deployment, exchange, and operation of digital service. Each of these dimensions are discussed below;

2.4.1. Service Provisioning

In achieving platform pluggability service provisioning aims to discover possible services and compare numerous existing services to assess specific services with relation to the business needs of municipalities in having contract with service providers (Rocha *et al.*, 2016; Aulkemeier *et al*., 2017). Hence, service provider can help by providing relevant information publicly and listing various service that can be provided to citizens and stakeholders in terms of service levels, usage policies, documentation, and pricing (Aulkemeier *et al*., 2016). Based on the proceeding discussion, the following proposition is made:

P1. Ease of service provisioning will significantly influence digital platform pluggability in smart cities.

2.4.2. Service Deployment

Different services provided by partners or enterprises should be easily installed, connected, and established in smart cities (Aulkemeier *et al*., 2016; Usurelu and Pop, 2017). By default, digital platform requires less technical installation and testing and thus, have an intrinsic advantage over conventional systems with regards to deployment (Aulkemeier *et al*., 2017). Thus, services provided by digital platform should support functional testing and learning with accessible documentation. Based on the above, the following proposition is stated:

P2. Ease of service deployment will positively determine digital platform pluggability in smart cities.

2.4.3. Device Adaptation

Digital platforms should be easily adapted to the functional needs of the citizens and stakeholders. This entails the ability to customize and configure services provided by digital platforms (Aulkemeier *et al*., 2017). A pluggable digital platform maximizes configurability while decreasing the need for customizations (Aulkemeier *et al.,* 2016). Based on the discussion the following proposition is stated:

P3. The adaptation of device will significantly influence digital platform pluggability in smart cities.

2.4.4. Service Integration

Digital platforms should be able to share data and mutually communicate in order achieve the overall business process of urban operations (Rocha *et al*., 2018). The integration of dedicated systems in cities is important and should be supported by different service providers, for example service integration can be achieved by employing adapters or integrators (Aulkemeier *et al.*, 2017). This will help system platforms to be able to share and exchange data without other service quality being affected, when services are provided to citizens (Aulkemeier *et al.*, 2017). Based on these arguments, the following proposition is made:

P4. Service integration will positively impact digital platform pluggability in smart cities.

2.4.5. Service Operation

Service operation aims to enable the continuous use of a digital platforms, by providing monitoring, maintenance, and end users support (Aulkemeier *et al*., 2016). Service providers can support service operation of digital platforms by providing service usage agreements for bug fixing and service requests, as well as offer suitable infrastructure such as support portals, help call centers, and bug tracking systems (Aulkemeier *et al*., 2017; Rocha *et al*., 2018). Hence, based on the above the following proposition is stated:

P5. The quality of service operation will significantly influence digital platform pluggability in smart cities.

2.4.6. Service Exchange

Loose coupling is an important for digital platforms as it facilitate the exchange and usage of services (Usurelu and Pop, 2017). Nevertheless, loose coupling of digital platforms requires the integrating of independent services to achieve pluggability in smart cities (Aulkemeier *et al.*, 2017). Thus, this study proposes that:

P6. Service exchange will positively impact digital platform pluggability in smart cities.

Based on the identified pluggability dimensions for digital platforms a model is proposed as shown in Figure 3.

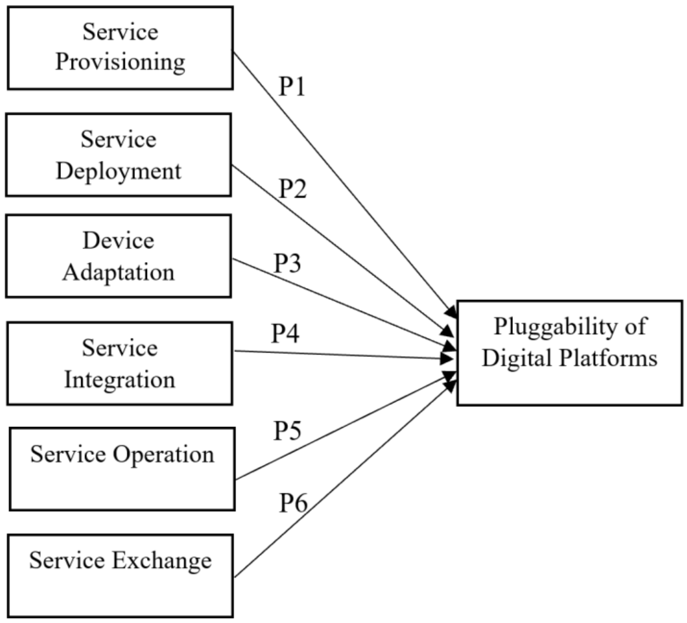

Figure 3 Pluggability dimensions for digital platforms

Figure 3 depicts that the dimensions needed to be considered to achieve pluggability of digital services comprises of service provisioning, service deployment device adaptation, service integration, service operation and service exchange of digital service. These dimensions significantly impact the pluggability of digital platforms for smart urban transformation based on the development and usage. Therefore, the pluggability dimensions for digital platforms supports the ability of adding and removing software or hardware components (urban platform adaptation) in urban environment in order to fulfil citizens and stakeholders needs (Rocha *et al*., 2018). The pluggability dimensions for digital platforms in urban environment facilitate seamless connection of pervasive systems that generates and process data (Aulkemeier *et al.,* 2017). However, in the study only the service integration (P4) will be addressed as the other dimension are out of the scope of this paper. This study is mainly concerned with service integration as it supports digital platforms to interact with each other without requiring much modifying of communication protocols and standards (Usurelu and Pop, 2017). Furthermore, findings from this section suggest that although pluggability has been investigated in smart urban context, none of the reviewed studies explored how to model service integration as regards to pluggability attainment in smart urban context. Therefore, this current study grounded on the information system perspective employs enterprise architecture framework to model how pluggability mainly service integration is achieved for smart urban transformation.

2.5.Overview of Enterprise Architecture Framework

As architects provides blueprints for (re-)designing structures, enterprise architects utilize Enterprise Architecture (EA) modeling languages for (re-)designing and transformation of organizations (Antunes *et al*., 2013; Jnr *et al.*, 2020). EA is a component of IS theories that can be employed to design digital platform landscape suitable for urban operations (Plataniotis *et al*., 2014). Thus, EA is a blueprint, plan of record, structure, configuration, groupings of Information Technology (IT) resources required to support organizational business function

(Pourzolfaghar *et al.*, 2019). In urban context EA includes set of principles, models, and methods that provide a holistic view of a municipality and guides the design and realization of its city structure, business processes, and IS infrastructures (Anthony Jnr, 2020). EA aims to help in the creation and communication of an understanding of a city's current state, desired future states, and the design to ensure urban transformation processes (Manzur *et al*., 2015).

Likewise, an Enterprise Architecture Framework (EAF) provides information to support the planning, management, and improvement processes of transformation. It also supports the re-engineering, optimization, governance, and decision-making processes of urban transformation (Antunes *et al.,* 2015). EAF modelling play a significant role in transformation of digital services in urban space (Bokolo and Petersen, 2020). EAF modelling describes how business processes are realized by digital platforms (Caetano *et al.*, 2017). EAF supports integration, by allowing the design of models that show high-level structures visualization and relations within domains (Jonkers *et al*., 2017).

2.5.1. Background of EAF Modeling Languages

In information system, modeling is an approach for systems analysis and design that helps with minimizing complexity and improving the involvement of prospective users (Frank, 2014). EAF models provide a better understanding of dependencies between IT and business components. EAF models are developed based on modeling language that provide views for communication between stakeholders with different backgrounds (Frank, 2002; Bock and Frank, 2016). Modeling language employs graphical notation with a semantics, and syntax that offers graphical symbols that supports visualization for better understanding of the associated domain (Frank, 2014; Pittl and Bork, 2017). Existing modeling tools includes Archimate, Business Process Model and Notation (BPMN) (Pittl and Bork, 2017), MultiPerspective Enterprise Modeling (MEMO) (Frank, 2002), 4EM (Pittl and Bork, 2017), and ADOxx (Bock and Frank, 2016).

In this article Archimate is employed for modeling smart urban transformation in EAF similar to prior studies (Brand *et al.,* 2015; Pittl and Bork, 2017; Pourzolfaghar *et al.*, 2019; Jnr *et al.*, 2020), and further explores how service integration is achieved to support pluggability of pervasive platforms. ArchiMate is an Open Group standard developed as an EAF independent, open, and general modeling language (Lankhorst, 2004). It provides an integrated architectural model that describes and visualizes the different layers and their underlying dependencies and relations (Iacob *et al.*, 2014). ArchiMate can be employed as an appropriate modeling tool for describing digital ecosystems (Pittl and Bork, 2017). ArchiMate is mainly modelled based on business layer, an application layer as well as a technology layer (Caetano *et al*., 2017). In ArchiMate's latest version 3.1. two extensions (motivation and implementation & migration) are added (Manzur *et al.*, 2018). The ArchiMate meta-model layers consists of three types: active structure, behaviour element, and passive structure (Jonkers *et al*., 2017). However, a major drawback of ArchiMate is that its classes are generic and do not provide property information. Hence, profiling and specification extension plugin can be used (Pittl and Bork, 2017).

3. Developed Enterprise Architecture Framework

To address pluggability and integration of different pervasive platforms needed to provide digital services for smart urban transformation, EAF is developed. Accordingly, this study presents an EAF for smart urban transformation (Petersen *et al.*, 2019; Jnr *et al.,* 2020). The developed EAF is shown in Figure 4.

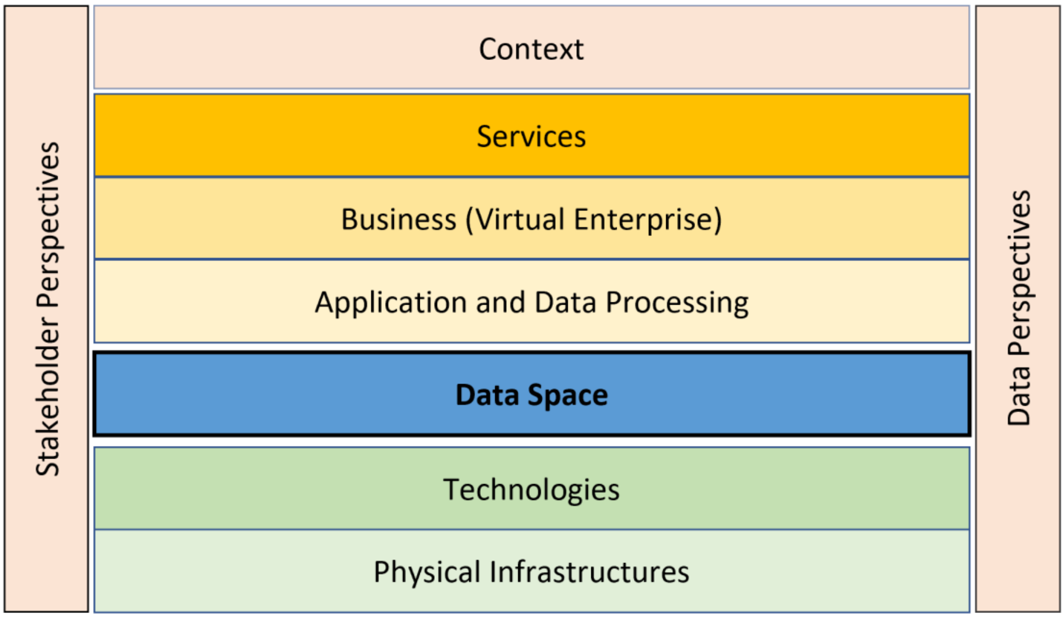

Figure 4. Developed enterprise architecture framework

Figure 4 depicts the developed EAF to support pluggability and integration of different pervasive platforms needed to provide digital services for smart urban transformation based on seven layers (context, service, business, application and data processing, data space, technologies, and physical infrastructures), and perspectives (stakeholder and data). Each of the layers and perspectives are described below;

3.1.1. Context

The context layer captures the interests of city stakeholders and citizens (Pourzolfaghar *et al.* 2019). The context layer also entails desires, need and requirements that relate to stakeholders' concerns, and associated Key Performance Indicators (KPIs) that improve quality of life of citizens (Petersen *et al.*, 2019; Jnr *et al.*, 2020). This layer comprises of the set of goals, constraints, principles and main requirements related to smart urban transformation (Anthony *et al.*, 2019).

3.1.2. Service

The service layer is responsible for presenting the municipality's action plans, resources, and capabilities (Bokolo and Petersen, 2020). It consists of high-level processes provided by the municipality facilitating enterprises collaborating to provide digital services to citizens (Berkel *et al.*, 2018). Therefore, this layer aims to effectively implement specified outputs and competently realizing specified key performance goals towards smart urban transformation (Anthony *et al.*, 2019).

3.1.3. Business

The business layer is responsible for presenting all partners or enterprises collaborating to providing pervasive platforms (Jonkers *et al*., 2017), and orchestrating urban activities in order to deliver digital services to citizens (Caetano *et al*., 2017). 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 digital services to citizens towards smart urban transformation (Anthony *et al*., 2019).

3.1.4. Application and Data Processing

This layer includes all digital platforms deployed to provide digital services to citizens and stakeholders (Aulkemeier *et al*., 2016). This layer utilize data from the data space layer in providing digital services (Caetano *et al.,* 2017; Anthony *et al.,* 2019). Moreover, this layer processes and transforms data into useful information to provide insights to decision makers towards smart urban transformation (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).

3.1.5. Data Space

The data space layer is the intelligence processing of the architecture as it includes data required to facilitate digital services (Otto *et al.,* 2017). Additionally, data space layer specifies which data is available and are utilized by enterprises collaborating to providing digital services (Petersen *et al*., 2019). The data space layer consists of data from pervasive platforms in urban environment. It includes real-time raw data (directly from the devices and sensors), processed online data from digital platforms deployed in cities, processed historical data and lastly third-party data (for external sources) (Anthony Jnr *et al.,* 2020).

3.1.6. Technologies

The technologies layer entails all the technologies deployed across the municipality such as edge, fog, cloud computing, ubiquitous computing, big data, processing, service-oriented architecture, etc. (Jonkers *et al*., 2017). This layer provides the required software and hardware infrastructures needed to provide smart services (Berkel *et al.*, 2018). Also, this layer deploys either cloud-based or locally run servers (Aulkemeier *et al.,* 2016). This layer also consists of infrastructures deployed to collect, process, handle, and temporarily store real-time data (Caetano *et al.,* 2017).

3.1.7. Physical Infrastructures

The physical infrastructures layer comprises of physical assets or hardware deployed within the city (Berkel *et al*., 2018). Physical infrastructures layer produces real-time data 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 raw data (Anthony *et al.,* 2019). In this layer data can also be collected from mobile and handheld devices that generates online data from social media, municipality websites, dashboards, etc. (Berkel *et al*., 2018).

3.1.8. Stakeholders and Data Perspectives

As shown in Figure 4, in addition to the horizontal layers, the EAF considers the stakeholder perspective and data perspectives (Petersen *et al.*, 2019; Bokolo and Petersen, 2020), which contributes to help support pluggability and integration of different pervasive platforms. The stakeholder perspective ensures a citizen focused approach, participation and collaboration of public and private entities call for close attention to the diverse stakeholders (e.g citizens, municipalities, enterprises, etc.), that are a part of the urban space. Stakeholders perspective also ensure awareness of the relevance of privacy and trust, data ownership and access, on the policies and regulations related to digital services provided (Petersen *et al*., 2019).

Correspondingly, 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 EAF, from the data sources to the value added services. The data perspective considers data interoperability, data standards, security, risk assessment, and data governance (Petersen *et al*., 2019).

4. Research Methodology

This study followed the Design Science Research Method (DSRM) which is a problem-solving approach that aims to create innovations that define products, ideas, technical capabilities, and practice through which the analysis, design, deployment, and use of IS can be efficiently and effectively accomplished (Peffers *et al.*, 2008). DSRM offers specific guidelines for iteration and evaluation within research projects (Jnr *et al.*, 2020). It focuses mostly on the development and performance of artifacts (Hevner *et al*., 2004). The DSRM comprises of six steps: problem identification, definition of the solution objectives, design and development of the solution artifacts, demonstration, evaluation and communication. Therefore, DSRM is adopted to structure this study as recommended by Hevner *et al.* (2004); Peffers *et al.* (2007). A general overview of the DSRM is shown in Figure 5.

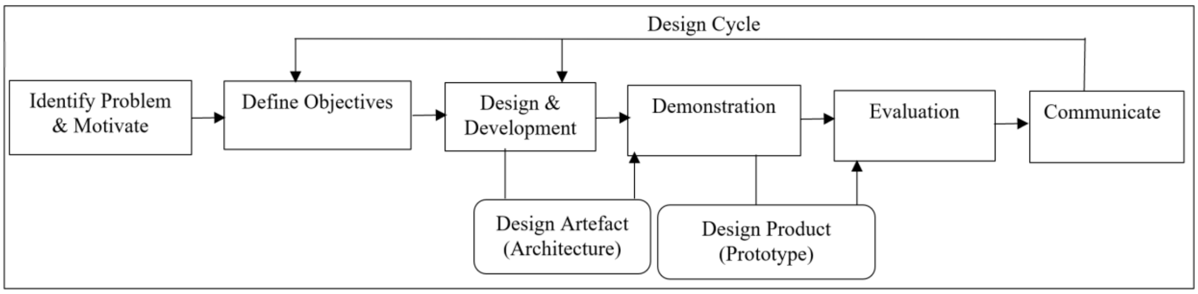

Figure 5 Design science research methodology (Hevner *et al.*, 2004; Peffers *et al.*, 2007)

Figure 5 depicts the design science research methodology. The first phase "identify problem and motivate" involves defining the research problem and rationalize the value of a solution to motivate research to pursue solution to the identified problem. Thus, this study aims to address support service integration of different pervasive platforms needed to provide digital services for smart urban transformation. The next phase define objectives of a solution involves specifying possible and feasible solutions based on knowledge and definition of the problem. In this study this phase includes employing the developed EAF as seen in Figure 4 to address the problems highlighted in the previous phase.

Design and development phase mainly involve creating the artifact which can potentially be a model, instantiations, methods, etc. Thus, this phase describing how the EAF support system pluggability of numerous actors and systems needed for smart urban transformation. This phase is specified in section 3 of this paper. Demonstration and evaluation involve use of the artifact to address one or more cases of the problem. Hence, in this stage, the developed EAF is presented to evaluated by means of multi-case studies in order to assess the practicality or usefulness of the architecture. The demonstration and evaluation phase are described in section 5 of this paper. Communication entails communicating the developed artifact to researchers and practitioners in scholarly research avenues.

4.1.Multiple-Case Studies Approach

The case study method was adopted to explore the developed set of requirements for EAF needed to support service integration of different pervasive platforms needed to provide digital services for smart urban transformation. A case study is a qualitative approach of enquiry which allows in-depth inquiry of an event within real-life context (Yin, 2009). Case study approach is appropriate for urban study in the information systems domain and can be employed to capture the richness of urban behaviour (Junior *et al*., 2018). Another reason for adopting the case study is the type of research questions, such as how EA can help resolve system pluggability. Yin (2009) recommended that how questions are more appropriate in case study research, as they reflect a deeper investigation of the research phenomenon.

Accordingly, the multiple-case studies is employed to be able to integrate data or evidence gathered from several cases. This ensure that more compelling outcomes is achieved with better potential for explanation (Jnr *et al*., 2019). Additionally, Yin (2009) advocated for researchers to employ multiple case studies to achieve strong base for model building. Junior *et al*. (2018) encouraged using multiple case studies to gain consistent findings. Thus, the results of multiple-case studies are much grounded, and are easily generalizable (Anthony Jr, 2018). Despite all of the benefits that a case study has to offer, there are a few limitations in employing this case study approach. Among these setbacks case study data collection is faced with subjectivity that can compromise the validity of findings. Also, it is challenging to generalize the findings of case study findings. Irrespective of these limitations, this study aims to employ the developed EAF using ArchiMate for modelling the integration of different pervasive platforms needed to provide digital services for smart urban transformation.

4.2.Background of Case Studies

To maintain anonymity, the organizations will be referred to as case study A and B. Case study A was selected for this study because it aims to decrease Greenhouse gas emissions from transportation sector to 85% in 2030. Case study A is a municipality in Norway that has more than 100 employees. Case study A targets to holistic transform transportation within the city to achieve a sustainable shift by adopting environmentally friendly policies. Furthermore, Case study A is working towards developing strategies required to decrease CO_2 emission by deploying novel renewable mobility solutions. Also, in achieving smart urban transformation, Case study A is using available open data to develop digital services towards improving citizen involvement and sustainable development.

Likewise, case study B is an organization in Norway that provides different digital services and infrastructure platform that manages distributed transportation and mobility operations for public transport operators within Norway and across Europe. Case study B was selected based on the company's prior knowledge in smart mobility in urban context. Case study B has several employees with its main offices in Norway. For the past decade case study B have achieved practical experience with deployment, development, and maintenance of digital solutions towards digital transformation of cities. Case study B deploys technological platforms to deliver innovative business and IT capabilities to their clients. Case study B is involved with providing digital service for urban transportation transformation in Norway.

4.3.Data Collection Instrument

To collect the necessary data, this study utilized multiple data collection methods, as recommended by Yin (2009). Using semi-structured interviews relevant information was gathered from both organizations. The semi-structured interview was mostly conducted in form of meeting discussion with participants from the two case studies to receive insights regarding how integration of pervasive platforms can provide digital services. The interview session was carried out by two researchers from the +CityxChange project (https://cityxchange.eu/). Furthermore, documentation provided in the organizations website that relates to digital service such as eMobility were used to gain a better understanding of the organizational context. The information gathered from these document reports were utilized as input for modeling how digital service for eMobility can be modelled in the developed EAF with the help of the ArchiMate language. As seen in Table 1 the participants included from both organizations comprises 9 participants.

Table 1 Profile of interview discussion participants

Case Studies	Present Title	Qualification	Present Role and Responsibilities
Case Study A	Data scientist	Masters	• Designs EA for smart urban services. • Design data-driven models for sustainable future.
	Project leader	Doctorate	• Design low-emission fossil-free electric vehicles and fleet platforms. • Initiate polices for eMobility, sustainable infrastructure and green urban transportation.

	IT architect specialist	Masters	• Project team lead on urban integration platform. • Integration development and architecture. • Smart urban requirement analysis.
	Project co-ordinator	Masters	• Co-ordinates smart and sustainable urban strategies.
	IT architect specialist	Doctorate	• Design digital services for smart urban transformation. • Directs smart city integration and EA modelling.
Case Study B	Chief architect specialist	Masters	• IT architect for eMobility transportation solutions.
	System developer	Bachelor	• Pervasive infrastructure testing, web-based socket, and interactive eMobility platform interface design.
	System architect specialist	Masters	• User interface development of eMobility platform solutions.
	Mobile application developer	Bachelor	• Implement Android application platform for eMobility digital services.

Table 1 the characteristics of the interviewees for the two cases. The interview discussion was employed for data collection as it aims to offer practical insight on participant's perception on integration of pervasive platforms (both software and hardware) and how the EAF can be adopted to improve eMobility services for urban transformation. The interview was performed face-to-face in a conversational style, opening with a discussion on the need for the developed EAF (see Figure 4) to support service integration of different pervasive platforms needed to provide digital services for eMobility towards smart urban transformation. The interview was carried out in English language and was manually written down and not recorded by the interviewers. Data was collected for an average of 1 hours in different locations.

The interview discussion questions include discussion on the background of the EAF and how each layers of the architecture can be applied to support digital services for eMobility. The participants were encouraged to provide feedback concerning the modeling of pervasive platforms and actors (stakeholders) in the architecture during the discussion. After the interview session, one of the interviewers sketches a summary of the findings relating to the architecture in relation to how eMobility service is to be implemented. Subsequently, the interviewers sent a preliminary model of the eMobility service in ArchiMate to participants in involved in providing evidence for further feedback and iterations. Therefore, findings from the interview discussion session was used to confirm the practicality or usefulness of each layers of the developed EAF presented in section 3.

4.4.Data Analysis Method

Thematic analysis which is one of the most widely used qualitative data analysis approach was employed for analysis of the interview data. Thematic analysis mainly identifies, analyses and interprets patterns of themes or meaning within data provided by the participants (Braun and Clarke, 2006; Anthony Jr, 2018). Thematic analysis is based on a process of clustering data to preidentified categories or themes. It was employed as an approach for analysis as it offers flexibility to explore questions regarding informants' practices, experiences, perspectives, and behaviour (Guest et al., 2011). It allows the participants to discuss their perception regarding digital service integration in their own words and without constraints from fixed response closed questions (Braun and Clarke, 2006). Thematic data analysis can either be deductively or inductively (Braun and Clarke, 2006). The deductive method is mostly based on an existing theory-driven as data analysis is more interpretative since analysis aims to identify new themes from the dataset or via an existing theory as means through which to establish, code and interpret the data (Braun and Clarke, 2006; Guest et al., 2011). On the other hand, in the inductive method the themes identified are mainly linked to the data, where the researcher tries to fit the data into a pre-defined framework or theory. As in this study (see Table 2 and Figure 6), where findings from the interview is themed into the developed enterprise architecture framework as seen in Figure 4.

5. Findings (Data Analysis and Demonstration)

In case study research data analysis involves the categorizing and concept mapping aimed at making sense of the collected data to present the overall findings from the interview discussion sessions. Findings from each case study is summarized in Table 2 and discussed in section 5.1 and 5.2.

Table 2. Comparison of specific case evidences

EAF Layers	Case Study A	Case Study B
Context	• Stakeholders (citizens, municipality and other stakeholders, and e-mobility) • Key Performance Indicators (KPIs) (%transport moved, CO2 emission reduction, NOx emission decrease, annual return on investment, degree of renewable energy traded, decrease in simple payback time, and new jobs created) • Input parameters (Travel habit survey from municipality authority, bus emission from transport company, data of diesel/gasoline from statistics Norway, and data of basic factors from EU joint research institute)	• Contribute to eMaaS • Indicator for eMaaS uptake • Increase uptake of eMaaS
Services	• e-Mobility service • Green mobility marketplace • Flexibility market (local energy market)	• Seamless mobility • Traffic management • eMaaS service
Business	• Third party providers (Racks/charging provider & operator) • EV rental company (private transport operator) • ICT company (EV charger provider) • EV company (EV sharing, owner & operator) • Municipality transport provider (public transport operator)	• EV rental company (EV mobility operator) • Municipality transport provider (provide city buses for commuting) • Municipality (administration) • e-Mobility App. provider (provided e-mobility application) • Energy trading company (Manages energy trading)

	• e-Mobility App. provider (User App developer and operator, and cloud storage operator) • Payment company (payment solution provider)	• Payment company (process micro-payment) • ICT company (data and EV charger provider)
Application and Data Processing	• Mobility platform backend • Rental service application • User App. • APIs (for input data) • Micro payment solution • Monitoring and evaluation system (for impact calculation) • Fleet management • Smart Cities Information System (SCIS)	• Total Traffic Control (TTC) application backend processing • Micro payment • eMaaS App (Android\Web) • APIs
Data Space	• Transport company cloud storage • Data from mobility solutions/mode	• Multiple data sources • Meta data • Car sharing data • 3rd party data road status, weather, etc.
Technologies	• Cloud server • Vehicle-to-Grid (V2G) charger	• Vehicle-to-Grid (V2G) charger • Server • Some technology • Micro payment infrastructure
Physical Infrastructures	• e-Bike Parking Racks • e-BikeCharger • Buildings (e.g that generates energy) • Electric Vehicles (EVs) • e-Bikes • EV bus charging stations • Parking hub • Buses • Ferries	• EVs • e-bikes • Buses • City bikes • Car sharing • Micro mobility • Public transport • EV charging stations • Flights • Taxis

5.1.Findings from Case Study A

Case study A goals is to actualize a change in behavior for instance to deploy a more sustainable urban transportation practice which can be facilitated by both digital or physical initiatives. Data was provided by the informants from the municipality. As stated by the project leader "*Case study A seeks to establish a marketplace a "one-stop shop" for shared green mobility for citizens within the municipality*". The project coordinator added that case study A "*aims to understand how this can be achieved based on actual KPI measurements*" presented in the context layer as seen in Table 2. The service layer also comprises of e-Mobility service, green mobility marketplace and flexibility market (local energy market). In the service layer findings from the project leader highlighted that the main service to be achieved by Case study A is "*Seamless Mobility*".

This service will support citizen to plan and undertake desired journey from one location to another while being informed about changes in the conditions of the various platform service providers and the citizens can alter the journey respectively. As mentioned by the informants from case study A "*the business layer of virtual enterprises comprises of third-party providers who manages the parking racks/charging provider & operators, EV rental company who are private transport operator, an ICT company who provides EV chargers, EV company who are the owner and operator of EV sharing*". Also, the project coordinator stated that "*the business layer comprises of the municipality transport provider who operates public transport, e-Mobility App provider which the company that develop and operates the user app, and cloud storage operator. Lastly, the payment company process micro payment of eMobility services".*

The informants stated that the application and data processing layer comprise of different applications as shown in Table 2. "*The mobility platform backend processes data received from all mobility solutions/modes. Then, the rental service application which utilizes rent-based administration, management, and booking system for EV sharing". Another application is the User App (mobility platform) that supports EVs and e-Bike sharing scheme. The user app pulls in e-mobility related data from third party providers on the total status of available EV parking racks, charging systems and operations. "Besides, micro payment solution is employed to achieve the marketplace by providing an integrated micropayment solution. This helps citizens to reserve and pay for mobility in one operation ensuring feasibility". "Also, there exist a monitoring and evaluation system support impact calculation of eMaaS adoption within the city. Lastly, a fleet management helps to manage all EVs deployed within the city and the smart cities information system receives information on eMaaS usage and KPI achieved within the city".*

As pointed out by the data scientist the data space layer *"comprises of cloud storage data provided by the city transport company on bus information and data provided from other mobility related solutions and modes".* Findings from the interview session suggest that the technologies layer comprises of *"cloud server that the eMobility App is connected to, EV chargers (2-way chargers), V2G that are pluggable and can be connected to buildings within the city. As this enables EVs to recharge when energy prices are low ensuring the range/availability on the EV, and the EVs can feed energy into the building and local grid when energy prices are favorable for selling".* Thus, as stated by the informants "*EVs will be connected to the project local energy market".* According to the data scientist and IT architect specialists, the physical infrastructures layer *"comprises of building in the city that generated renewable energy via solar, wind, etc., shared electric vehicles (EVs), e-Bikes, city bike, e-Bike parking racks, e-Bike charging facilities, and all public transport operated within the city such as (buses, ferries, etc.)".*

5.2. Findings from Case Study B

Findings as reported by informants from case study B indicates that to achieve service integration the organization aims *"to contribute to eMaaS, improve the indicator for eMaaS uptake and increase uptake of eMaaS*" in relation to the context layer as stated by the chief architect specialist and system architect specialist. For the service layer the system architect specialist stated that case study B is working "*to provide a pluggable digital platform that provide seamless mobility for citizens by offering an eMaaS service within built traffic* *management*". Findings from case study B as regard to the business layer is similar to findings from case study A. Where the enterprises involve in providing integrated eMobility services comprises of "*EV rental company which provides EV mobility operator, municipality transport provider who provide city buses for commuting, Municipality administration, e-Mobility app. provider, energy trading company who manages energy trading, payment company that process micro-payment and lastly the ICT company that offers data and EV charger services within the city*".

Additionally, the mobile application developer and system developer mentioned that the application layer "*comprises of the TTC application backend which collects and processes mobility data via APIs to be used by the eMaaS App (Android\Web). Also, this layer comprises of the micro payment application which process eMobility payment"* similar to findings reported from case study A. Findings from the system architect specialist suggest "*that data are integrated via APIs from multiple data sources, meta data, car sharing data, and data from third party such road status, weather, etc.*". These data are used to ensure that eMobility services are provide to citizens. As pointed out by the system architect specialist the technologies layer *"comprises of different technologies such as hardware and software which are integrated to achieve a pluggable eMobility service. The technologies include V2G charger, remote server, some technology, and micro payment infrastructure".* Lastly, the chief architect specialist and system architect specialist mentioned that the physical infrastructures layer comprises of various eMobility options available in the city such as *"EVs, e-bikes, buses, city bikes, car sharing, micro mobility, public transport, EV charging stations, flights and taxis*".

5.3.Demonstration and Modelling of Findings

Findings from both cases are presented in developed EAF artifact (see Figure 4) in ArchiMate to model how service integration is achieved as seen in Figure 6. Thus, Figure 6 depicts combined findings from the interview discussion as a meta-model to support integration of pervasive platforms of e-Mobility service needed to provide digital services based on an eMobility case scenario for sustainable transportation. The notations used to depict each pervasive system, data sources, actors, relationships, etc. are based on the ArchiMate 3.0 specification (The Open Group, 2016). Although, the platforms are all located in the application and data processing layer to enable service integration pluggability with minimum effort, the other layers in the developed EAF are described as data can be provided from the IoT devices installed in physical infrastructure layer and software and hardware deployed in technologies layer. Hence, Figure 6 depicts how service integration can be achieved based on the developed EAF used to conceptualize the main pervasive platforms, entities, and relationship types which relates to the seven layer in the developed EAF (context, service, business, application and data processing, data space, technologies, and physical infrastructures), required for eMobility service in smart city.

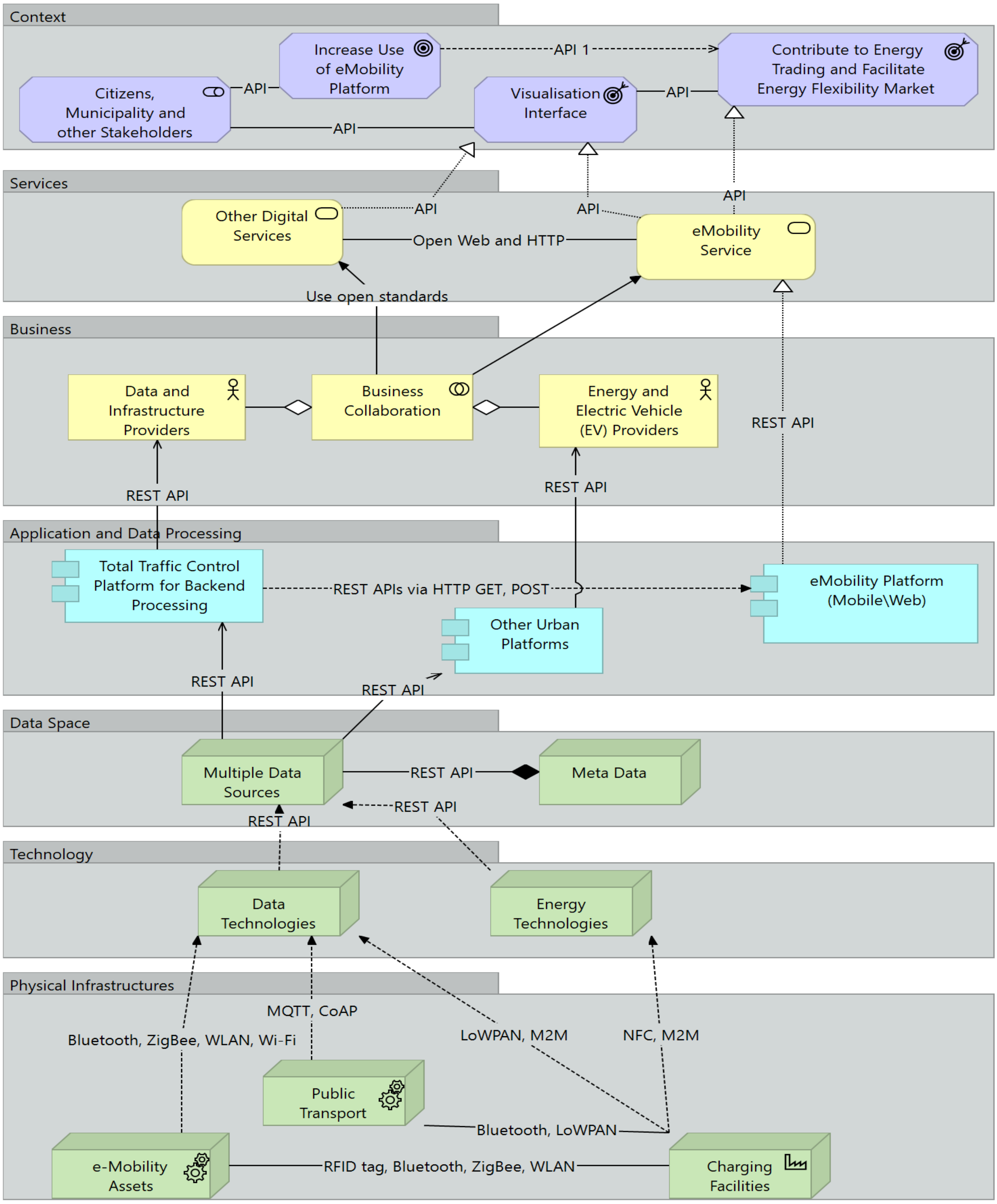

Figure 6. Meta-model to support pluggability and integration of pervasive platforms

Furthermore, as seen in Figure 6 from the physical, technology and data space layers, different pervasive systems, devices, data and infrastructures are being deployed by several actors (in the business layer). They may be the owners of the pervasive software, hardware and data utilized to provide digital services such as eMobility services for stakeholders along the different horizontal layers (the stakeholder and data perspective as discussed in section 3.6.8). Thus, other layers in the developed EAF are important as well. Also, Figure 6 shows how data from multiple data sources and platforms integrated based on different communication protocols and web standards to achieve service integration of pluggable digital platforms.

6. Discussion and Implications

6.1.Discussion

In municipalities the deployment of pervasive platforms is complex and can be considered as a challenge for urban development. Also, the description of pervasive platforms in urban context with existing approaches is unfeasible (Pittl and Bork, 2017), as they currently lack in expressiveness when describing digital systems (such as IoT, big data, etc.) and services provided (Anthony Jnr, 2020). Furthermore, the pluggability, mainly service integration of pervasive platforms in cities is challenging and constantly changing due to technological advancement (Nota *et al*., 2018). Similarly, in smart urban transformation the integration of different pervasive platforms that provides digital services is not adequately achieved because of different systems from different actors (Jnr *et al*., 2020). Therefore, this study discusses theories on digital platforms and grounded on information systems perspective and presents the application of EAF for designing a model-driven approach for achieving digital service which encompass the service integration of software components as well as hardware components.

Data collected via semi-structured interviews suggest that EAF provides the structure to manage changes and maintain urban transformation and aims to align the business with the underlying IS from the perspective of the stakeholders (Jonkers *et al.*, 2017; Berkel *et al.*, 2018). Findings from the case studies discussion illustrates that the context layer captures the KPIs to be achieved for smart urban transformation. As started by Petersen *et al.* (2019), this layer captures requirements or interests of citizens, municipality, and stakeholders via APIs on their devices and web portals for decision making regarding eMobility usage, visualization, contribution to energy trading and facilitation of energy flexibility market. Findings reveal that the service layer captures the digital services provided by business that collaborates. This result is analogous with findings from the literature (Chourabi *et al.*, 2012; Brand *et al.*, 2015), suggesting that these services are internally achieved by business processes that utilize and transform business goals which are performed by business actors. The various services in the service layer are made pluggable via REST API and HTTP standards (Li *et al.*, 2016; Mukti and Prambudia, 2018).

Furthermore, findings from the case study confirm the business layer comprises of several partners who collaborate to provide digital services to citizens such as citizens, businesses, etc. This finding is in line with results discussed by prior studies (Pourzolfaghar *et al*., 2019; Berkel *et al*., 2018). Additionally, as seen in Figure 6 findings suggest that the business layer comprises of all the actors involved that collaborates to provide eMobility services performed in providing digital services such as eMobility service, flexibility market, traffic management, green mobility marketplace, and other services for smart urban transformation. The application layer involves how data is processed and utilized by the eMobility platform used by citizens to manage transport booking collect data as highlighted by Anthony Jnr (2020), from the total traffic control platform which is also connected to the fleet management system via HTTP standard.

Findings from the data space layer suggest that this layer comprises of commercial, private, and open data from third parties such as weather forecast, road traffic status, EV status etc. This finding is also consistent with results from the literature (Sebastian *et al.*, 2018; Rodríguez Bolívar, 2019) which suggest that urban data repository is organized, accessed and identified using significant blocks of information, to ease accessibility. Hence, the data space is a data repository that provide meta data, real-time\online data and historical data to support platform pluggability in providing digital services via open and linked data. As seen in Figure 6 data from different sources are used to support e-Mobility services. The data are provided in JavaScript Object Notation (JSON) and XML format to be easily processed to support the urban services via REST APIs as recommended by prior studies (Aulkemeier *et al.,* 2016; Aldea *et al*., 2018; Antonova, 2018).

Additionally, finding from the technology layer describes how pervasive platform are supported by technologies deployed for data communication, processing, and storage. Thus, this layer provides processed data either remotely (via the cloud) or locally from sensing devices, sensors and physical hardware to facilitate the operation of the upper adjacent layer (Rocha *et al*. 2016; Usurelu and Pop, 2017). As seen in Figure 6 findings from the technology layer comprises of the data and energy technologies which include digital integrity infrastructures, Vehicle-to-Grid (V2G), cloud server, micro payment infrastructure, and local grid. The technologies connect via Representational State Transfer (REST) Application Programming Interface (APIs) via Hypertext Transfer Protocol (HTTP) for pluggability of the system deploy using protocols such as Open Charge Point Protocol and LoRaWAN (V2G), WiMAX, Ethernet to integrate real-time data. This result is similar to findings presented by Rocha *et al.* (2016); Anthony *et al.* (2020).

Findings from the case studies confirm that the physical infrastructure layer produce real-time raw data collected in aggregate from legacy platforms, sensing devices, sensors and physical hardware which comprises eMobility assets, charging facilities, and public transportation as seen in Figure 6. This finding is analogous with results from prior studies (Brand *et al.*, 2018; Berkel *et al*., 2018). The generated data in the physical infrastructure layer are transferred to the technology layer for data handling as stated by Otto *et al.* (2017). As seen in the physical infrastructure layer communication technologies such as Radio-frequency identification (RFID), Bluetooth, ZigBee, WLAN, Wi-Fi, Near-field communication (NFC), LoWPAN etc. are utilized. The infrastructure also connects to data and energy technologies sources via machine-to-machine (M2M) connection, Message Queuing Telemetry Transport (MQTT), and Constrained Application Protocol (CoAP). This finding is in line with results from the literature (Pittl and Bork, 2017).

6.2.Implications of Study

This study provides implication to theory and practice towards smart urban transformation.

6.2.1. Theoretical Implications

Due to densely inhabited cities there is need to develop polices for design and management of cities. Similarly, it is required to develop more sustainable operational models, both for the management of city infrastructures and provision of digital services that rely on pervasive platforms. As such cities around the world are leveraging the potential of digital transformation by integrating pervasive platforms to support municipality administration to provide digital services to citizens at reduced costs and higher quality (Li *et al.*, 2016). Findings from this study presents the theoretical background related to digital platforms and theories on digital platforms which comprises of three diverse perspectives (economics, information systems, and organizational perspectives) to show how digital platforms evolves. In addition, this study explores the theoretical background of pluggability and developed propositions that significantly impact the pluggability of digital platforms for smart urban transformation based on the development and usage to guide future research in the area of pluggability.

Findings from this study based on semi-structured interviews present how cities can resolve system integration among pervasive platforms in providing digital services. Although, IT system integrators like IBM, Accenture, TCS are implementing different types of multivendor systems in enterprises. There a fewer research that explore platform integration and pluggability concept within urban context as regards to provision of digital services to citizens and stakeholders. Accordingly, a model-driven approach with enterprise architecture is developed to support cities in addressing the challenge of achieving system pluggability due to numerous actors and systems needed for smart urban transformation. Findings from the case studies shows how service integration of pervasive platforms can be achieved to provide digital service (eMobility service). In this way, the developed EAF serve as a starting point for model-driven digital service development. It also provides visualization of stakeholders, technologies, businesses, services, and KPI to be achieved by the city. The developed EAF architecture presented in this study can be adopted by policy makers to manage the digitalization of services as an integral part of sustainable urban development for the well-being of citizens, enterprises and governments institutions. Additionally, the developed EAF comprises of stakeholders and data perspective to capture different stakeholders and data sources involved in digital services provided in the city.

6.2.2. Practical Implications

Nowadays cities are struggling to manage and to replace legacy platforms with new platforms or systems. EAF modeling may help cities to integrate urban systems in a way to achieve a pluggable software and hardware components that can exchange data based on the service needs of citizens without platform constraints. This article presents an EAF that captures pervasive platforms deployed for eMobility service in urban environment, their dependencies and relations. The main contribution of this study depicts how EAF, using ArchiMate modeling language, can be employed to integrate different pervasive platforms deployed by different stakeholders communicating to co-create collective digital services to citizens. The developed EAF supports the process of information systems theory by providing urban developers with an adaptable and reusable blueprint for eMobility service.

Therefore, this article describes the development of an EAF that acts as a model-driven approach that providing a way to visualize smart urban digitalization with the help of ArchiMate. Also, stakeholder’s perspective aid in capturing each stakeholders’ own roles, interest, and business service to achieve an ecosystem of pervasive platforms used by all stakeholders. ArchiMate modelling is employed in this study to visualize stakeholders, their operation strategies and goals towards smart urban transformation. Findings enable researchers and practitioners to create interactive digital services highlighting the strategic value of EA. Finally, the developed EAF can also help municipalities with a bottom-up decision support model to improve communication and collaboration between municipality administration, researchers and practitioners interested in digital transformation of cities.

Findings from the modelled case suggest that the developed EAF enable stakeholders to collaborate, design, understand, and transform urban services for digital services. Practically, the design artifacts or metamodel presented in this study (see Figure 6) support pluggability, specifically integration of different pervasive platforms needed to provide digital services for smart urban transformation. More precisely, the developed EAF presented in this study provide a model that supports collection and exchange of data from different data sources in smart urban environment to the specific needs of stakeholder or enterprises to enable the provision and consumption of digital services. This helps to identify state of the art data sources and software systems. As observed from the multi-case studies, EAF can support integration of devices and sensors deployed in making cities smart.

7. Conclusion

A smart urban environment supports collaboration, data sharing, integration, and seamless services for all its residents anytime and anywhere within the city (Yovanof and Hazapis, 2009). The trend towards a digital driven economy leads to smart urban environment where cities deploy pervasive systems which are tightly connected to other system provided by various stakeholders and service providers. Likewise, municipalities provision of digital services is multifaceted and as such comprises of different pervasive systems (Hämäläinen, 2020). These connections of diverse pervasive systems lead to hardware and software that needs to be integrated and managed to have a pluggable urban ecosystem. One approach to capture these pervasive systems within urban context is by employing an enterprise architecture framework that integrates all pervasive platforms in a unified way.

Therefore, based on a review of theories for digital platforms mainly grounded on information systems perspective, this study presents an EAF to support pluggability mainly integration of different pervasive platforms needed to provide digital services for smart urban transformation. The design science research method was adopted using multi-case studies from two organizations in Norway. Data was collected from semi-structured interview discussion from both organizations regarding digital service for eMobility for urban transportation transformation in Norway. Findings from the case studies illustrate the smart urban transformation of eMobility operations models in smart urban context. The developed EAF provides insights on how pervasive platforms can be integrated to achieve an integrated digital service from different stakeholders and data sources in practice. Findings was demonstrated in ArchiMate as a meta-model to show how the developed EAF aids system pluggability of actors and systems in providing digital service for smart urban transformation. This research only employed multi-cases study to validate the service integration of the developed EAF. In our future work, the other pluggability dimension (service provisioning, service deployment, device adaptation, service operation, and service exchange) would be explored in detail in relation to other service provided in smart cities.

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