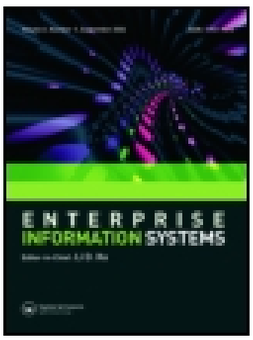

Enterprise Information Systems

ISSN: (Print) (Online) Journal homepage: https://www.tandfonline.com/loi/teis20

# Managing digital transformation of smart cities through enterprise architecture – a review and research agenda

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**To cite this article:** Bokolo Anthony Jnr (2020): Managing digital transformation of smart cities through enterprise architecture – a review and research agenda, Enterprise Information Systems

**To link to this article:** https://doi.org/10.1080/17517575.2020.1812006



Published online: 25 Aug 2020.

ENTERPRISE INFORMATION SYSTEMS
https://doi.org/10.1080/17517575.2020.1812006

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# Managing digital transformation of smart cities through enterprise architecture – a review and research agenda

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**ABSTRACT**

The recent growth in digital technologies are enabling cities to undergo transformations for streamlining smart services and offering new products. Digitization has changed the way citizens and stakeholders live, work, collaborate, and communicate. This disruptive change inter-connects with all information systems and processes that are important for providing services. Although, digital transformation present opportunities for achieving smart cities. Municipalities still struggle with managing data integration and complexity. Accordingly, this study systematically reviews 70 research articles from 1999 to 2020 and discusses on development and state-of-the-art of Enterprise Architecture (EA) and digital transformation of cities into smart cities.

**ARTICLE HISTORY**
Received 4 April 2020
Accepted 15 August 2020

**KEYWORDS**
Information systems; digital transformation; enterprise architecture; sustainable cities; smart cities; systematic review

## 1. Introduction

With nearly four billion people presently residing in cities, a global trend of digital-based urbanisation is occurring. An increasing number of municipalities are advancing their smart city development efforts (Bosdriesz et al. 2018). This movement has led to global investments and policy innovations for technological implementations and data utilisation to address social issues and urban growth (Anthony Jnr et al. 2020). Respectively, a smart city is a city that is able to generate, collect and process data to facilitate intelligent predictive and decisions analysis for better urban planning and development (Tomičić Pupek, Pihir, and Tomičić Furjan 2019). According to the United Nations (UN) definition a smart city is an innovative city that deploys Information and Communication Technology (ICT) and other mediums to enhance quality of life, efficacy of urban services and operation, and competitiveness, while ensuring that it address the needs of present and future generations in regard to social, economic, and environmental aspects (Salem 2016). Smart city development is based on digital innovations provided by enterprises which provide smart services to improve citizens quality of life (Jnr, Majid, and Romli 2018).

Smart cities involve innovative use of digitalisation which comprises of various forms of ICT that are infused to provide smart services (Goerzig and Bauernhansl 2018). A smart city is a social structure that brings together business, society, and technology (Anthony et al.

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2019). For a city to be smart the technological as well as the environmental, social, and human aspects should be considered (Mendhurwar and Mishra 2019). Smart cities are supported by digitalisation and technological innovations that brings about future environmental, social, and financial benefits (Bokolo and Petersen 2019). These digitally enabled cities are supported by ICT, referred to as digital technologies, which progressively promise enormous prospects for growth. Presently, digital transformation is one of the latest developments driven by technological progress which disrupts existing business models in different sectors (Gampfer 2018). Digital transformation involves applying digital technologies to several areas of an enterprise, which lead to important changes in enterprises' activities and the way values are created for stakeholders. Digital transformation aims to re-align processes, technology, and business models to create value for customers as well as enterprises (Vobugari, Srinivasan, and Somayajulu 2017). Digital transformation can bring about increased productivity and revenue, decreasing costs, improving client service (Aliee, Kashfi, and Farahani 2019). Digital transformation entails the connection of actors over the value chain and the deployment of systems for gathering, exchange, processing and analysis of city data to support decision making (Antonova 2018). Digital transformation involves the application of digital technologies to improve city performance and scale operations, services, and organisational structures (Goerzig and Bauernhansl 2018).

Presently, cities are faced with increased pressure to continuously develop in an integrated and fast-changing world (Hämäläinen 2020). To successfully adapt in such conditions, cities are expected to continuously adjust to changing environments (Babar and Yu 2015). Therefore, digital transformation enables human beings and autonomous devices to cooperate beyond their own context using Information Technology (IT) facilitated by big data, cloud computing, mobile and social technologies (Gampfer 2018; Zimmermann et al. 2018). Such a transformation is an important shift from the previous modus operandi and results in potentially disruptive urban-wide transformation enabling municipalities to move from conventional operation to digital based approach (Babar and Yu 2015). Transforming cities as a response to digital change is challenging and requires a structured approach particularly as cities comprises of different entities with different technological and social elements all of which can govern the success or failure of digital transformation (Babar and Yu 2015).

Furthermore, the increasing dynamics in both economy and technology imposes serious challenges for cities since there is need to adapt to complex changing conditions while at the same time ensuring system integration (Vobugari, Srinivasan, and Somayajulu 2017; Bosdriesz et al. 2018; Gampfer 2018). Although, findings from the literature (Salem 2016; Antonova 2018; Tomičić Pupek, Pihir, and Tomičić Furjan 2019; Hämäläinen 2020) examined digital transformation in smart city domain. They have not yet investigated how complexity and system integration can be improved. To address complexity and system integration faced in digital transformation of cities, this study opted for Enterprise Architecture (EA) approach to address the aforementioned issues. EA can be deployed to manage the digital transformation of cities infrastructures, and systems as well as, their relationships to each other and the environment, and the principles governing city's design and evolution (Gampfer 2018). Over the years, the concept of EA has grown as an approach to cope with these challenges by facilitating the management of Information Systems (IS) alignment with business elements within organisations (Gampfer 2018).

EA has been and still is a continually evolving domain which is shaped by technological advances and social progress as well as learning outcomes. EA has been employed by prior studies in smart city domain (Pourzolfaghar, Bezbradica, and Helfert 2016; Anthony Jnr 2020a; Jnr et al. 2020b). One key objective of EA is to integrate the different facets of cities aligned which includes business interests and information systems. EA has the potential to play a key role of increasing dynamics by enabling cities to effectively manage and transform services provided to citizens (Gampfer 2018). The remainder of this paper is structured as follows. Section 2 is literature review, and then section 3 is the method. Findings and discussions are presented in section 4. Section 5 is the implications of study. Lastly, section 6 is conclusion.

## 2. Literature review

During the last decade, an increased number of studies has conducted reviews on the importance of enterprise architecture or digital transformation in making cities smarter. Among these study Butschan et al. (2019) conducted a systematic literature review on the relevance of competencies in the context of industrial internet of things (IoT) to address the hurdles of digital transformation. Based on the review a competence model was derived to explore the role of individual competencies in resolving the challenges of digital transformation. Vial (2019) conducted a review on 283 studies to inductively develop a framework of digital transformation based on eight building blocks. The author further presented a research agenda to investigate the role of dynamic capabilities, and accounting for ethical challenges as significant medium for future strategic IS contributions on digital transformation.

Verhoef et al. (2019) carried out a multidisciplinary review and identified three stages of digital transformation which comprises of digitisation, digitalisation, and digital transformation. In addition, the authors outlined growth strategies for digital enterprises as well as the capabilities and assets required to effectively transform digitally, stating that digital transformation requires specific managerial structures for calibrating performance. Gampfer et al. (2018) conducted a systematic review to explore the past, current and future development in enterprise architecture evolution. The researchers presented a historical overview of EA development using artificial intelligence techniques such as supervised learning, text mining, and information retrieval side-by-side with manually checking of relevant articles. Moreover, they described the current focus of EA and made recommendations for future studies using predictive analytics.

Pourzolfaghar, Bezbradica, and Helfert (2016) carried out a review to identify types of IT architectures in smart cities domain based on business models and EA perspective. The authors explored on different architectures based on business context and also conducted an in-depth review of the well-known EA concepts to derive an evaluation framework for architectural requirements for business context for relevant smart service requirements. Lange, Mendling, and Recker (2012) employed literature review to identify success factors and benefits of EA after which the findings were integrated with the DeLone & McLean IS success model to develop a theoretical model to explain the realisation of EA benefits. Chen, Doumeingts, and Vernadat (2008) attempted to present a roadmap based on the review of past and present architectures for future enterprise interoperability and integration. The researchers clarified and defined basic concepts of

EA and also presented an overview on architectures for enterprise integration implemented within the 1980s. Their review mainly focused on recent advances of architectures for enterprise interoperability.

### 2.1. Gaps and limitations of prior studies

Based on the current literature, none of the above review studies have explored enterprise architecture and digital transformation in smart city domain. Nevertheless, several studies were carried out over the years, each of which provides significant information for academicians and practitioners to well understand the impact of digital transformation on smart cities as well as the contribution of EA on smart cities. It has been observed that research has ignored the review of studies related to the impact of EA on digital transformation to address complexity and system integration associated in smart cities. Hence, this study is motivated to carry out this systematic review. The present review study attempts to add value to existing body of literature by presenting an up-to-date synthesis of EA and digital transformation research studies that were mainly focused on improving smart city development.

## 3. Method

A systematic literature review is an important phase before conducting any research as it creates the basis for knowledge creation which helps to identify research gaps in existing research (Jr, Majid, and Romli 2017; Sahu, Padhy, and Dhir 2020). A systematic literature review is based on explicit research questions, analyzes relevant studies (Ng et al. 2018; Asmussen and Møller 2020), and assesses their quality based on defined criteria. In this review paper, the review protocol recommended by Kitchenham et al. (2009) is employed for conducting the systematic review. The review protocol comprises of six distinct phases: specifying research questions, stating the inclusion and exclusion criteria, search strategies and data sources, quality assessment check, data coding and analysis, and findings and discussions as seen in Figure 1.

Figure 1 depicts the review protocol. The details of each phases are described in the following sub-sections.

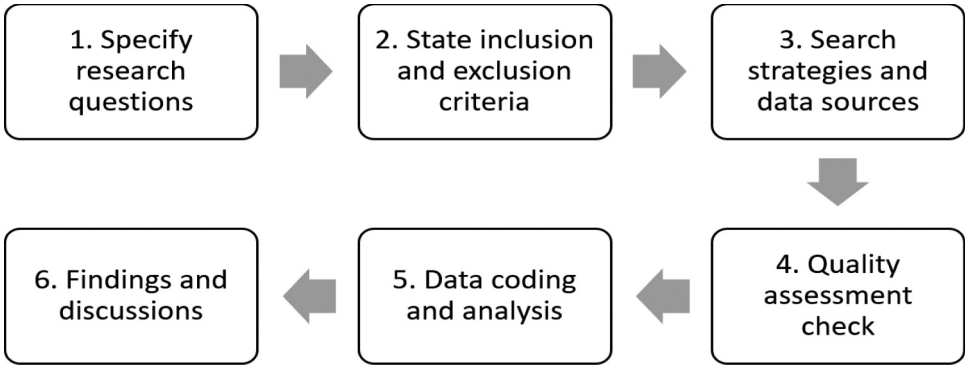


**Figure 1.** Review protocol adopted in this study.

### 3.1. Research questions

Research questions aid researchers to set scope for their work in addressing the problem to be resolved in the study. Accordingly, in this review study four research questions were formulated to guide the research. The framed research questions are as follows:

- RQ1: Why is digital transformation important and what are the phases of digital transformation in smart city domain?
- RQ2: What is the significance of EA towards digital transformation and which studies employed EA and/or digital transformation in cities or enterprise?
- RQ3: How can EA contribute towards digital transformation in smart cities?
- RQ4: Which exiting EA modelling tools can be deployed by scholars and practitioners in smart city domain?

### 3.2. Inclusion and exclusion criteria

The inclusion and exclusion criteria are specified to assess whether or not the retrieved papers are to be included to provide answers for the specified research questions (Anthony, Majid, and Romli 2020). The inclusion and exclusion criteria for this review study are presented in Table 1.

### 3.3. Search strategies and data sources

The research studies utilised in this review were retrieved through a comprehensive search of prior studies through Scopus and Web of science. The search was undertaken in October 2019 till January 2020. The search terms consist of the keywords ((‘digital transformation’ smart cit*” OR ‘enterprise architecture in smart cit*’) AND (‘digital transformation for sustainability’ OR ‘enterprise architecture and digital transformation’ AND ‘smart cit*’)) AND ‘industry 4.0’ AND ”internet of things” AND ‘Sustainable Development’ AND ‘Digitalization’ AND ‘Digitization’. The use of the keywords is an important step in any systematic review as it specifies which articles are retrieved (Kitchenham et al. 2009). The search results retrieved 107 articles using the above mentioned keywords. 2 papers were found as duplicates and were removed. Hence, the total number of remaining papers becomes 105. The remaining papers were assessed against the inclusion and exclusion criteria (see Table 1). Therefore, 56 articles were found to meet the inclusion criteria. After which 14 papers were added based on forward and backward citations and a total of 70 papers were included in the secondary data analysis process.

**Table 1.** Inclusion and exclusion criteria.

| Inclusion criteria | Exclusion criteria |
|---|---|
| Studies published in English language. | Studies that are not written in English language. |
| Journal articles, conference proceedings, book chapters, and weblinks. | Not journal articles, conference proceedings, book chapters and not weblinks. |
| Published between 1999 till date. | Published before 1999. |
| Studies that provide possible answers to research questions based on title and abstract content. | Remove similar studies by retaining the most current and complete version. |
| Studies related to EA and/or digital transformation in smart cities. | Studies not related to EA and/or digital transformation in smart cities. |

The study search and refinement phases in this review study were conducted based on the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) as employed by prior review study on digital transformation (Verhoef et al. 2019). Figure 2 depicts the PRISMA flowchart.

### 3.4. Quality assessment check

The Quality Assessment Check (QAC) is one of the crucial criteria that needs to be carried out to examine the quality of retrieved papers (Kitchenham et al. 2009). The QAC criteria assessed if the selected sources are indexed in Scopus or ISI Web of Science. Findings from the selected sources suggest that more than 50% of the selected papers are indexed in Scopus or ISI Web of Science.

### 3.5. Data coding and analysis

The final 70 studies were analysed descriptively to code, extract and synthesise the important themes of enterprise architecture and digital transformation in making cities

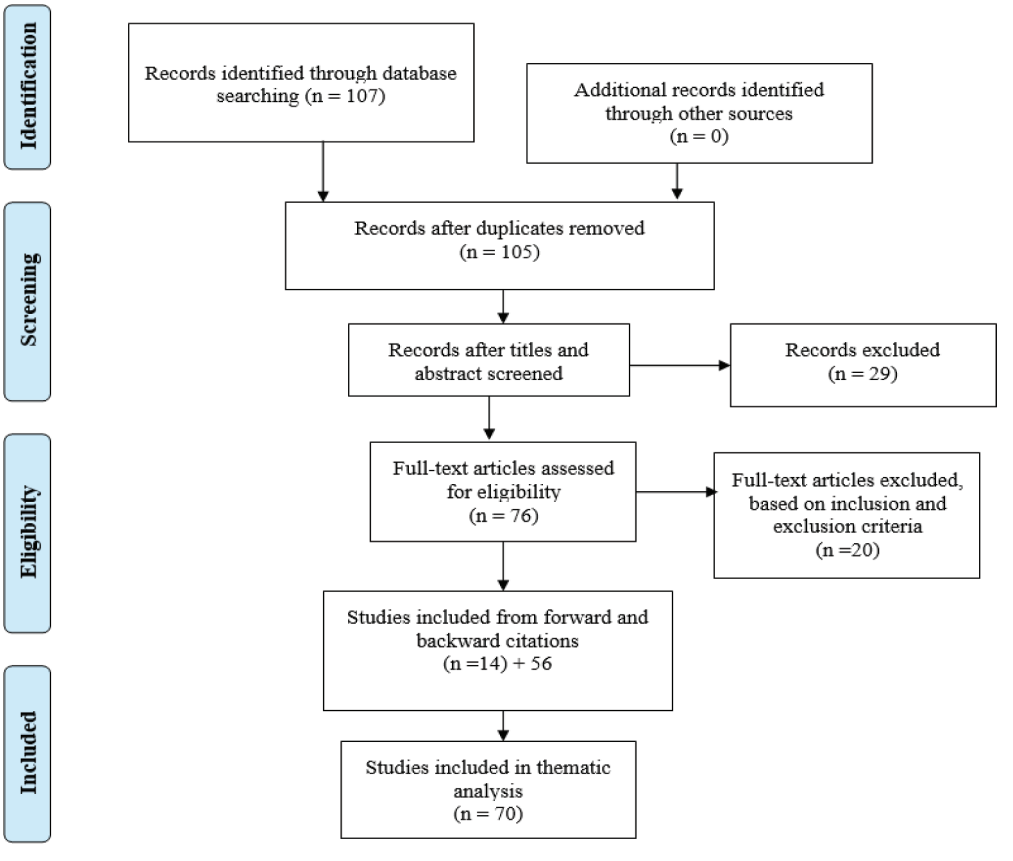


**Figure 2.** PRISMA flowchart for literature search process.

smarter. This phase of the study helps to better conceptualise the role of EA for digital transformation in smart cities. In the next section, findings from the reviewed papers are employed to provide answers to the research questions.

## 4. Findings and discussions

With respect to the selected studies about EA and digital transformation in smart cities from 1999 to 2020, the findings of this review study are reported based on the aforementioned research questions.

### *4.1. Importance of digital transformation in smart city domain*

Nowadays, we experience the transformative impacts of mobile, big data, social media, cloud, analytics and other technologies at faster pace (Kaur et al. 2020a, 2020b). These digital disruption marks the start of a new economic and technological paradigm (Berman and Marshall 2014; Jnr, Majid, and Romli 2020a). Digital transformation began as IT based transformations since 1985 as seen in Figure 3.

Figure 3 shows the milestones of IT-enabled transformation for digital transformation from the invention of Compact Disk (CD), email, and personal computer before 1985 and World Wide Web (WWW) by Tim Berners-Lee in 1990. Figure 3 also depicts other IT based transformation from the past 20 years (2000–2020) from web 1.0, web 2.0 and web 3.0. As seen in Figure 3, smart city is one of the IT-enabled transformations between 2015 and 2020.

Findings from the literature (Vobugari, Srinivasan, and Somayajulu 2017; Aliee, Kashfi, and Farahani 2019) revealed that municipalities that embraced digital transformation have gained gain knowledge and understanding critical to achieve competitive advantage over untransformed cities. Digital transformation in smart cities comprises of four main components which are data, people, digital technologies and their interrelationship as showed in Figure 4 (Ashwell 2017). The volume, velocity, and access to data in smart cities referred to as Big data is increasing at an unprecedented rate (Ashwell 2017). Digital technologies and processes have made it easier for citizens and stakeholders to secure, store, discover, exploit, retrieve and share data. Thus, past developments (Vobugari,

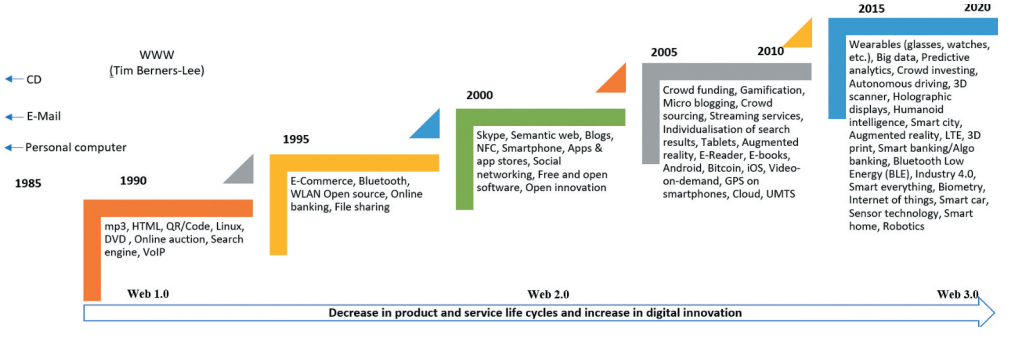


**Figure 3.** Milestones in IT-enabled transformation adapted from Dapp (2017).

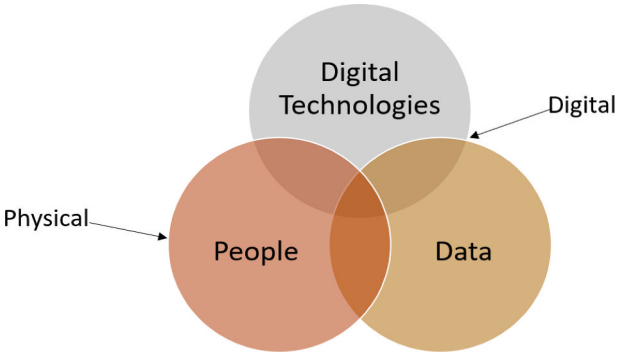


**Figure 4.** Digital transformation components in smart cities.

Srinivasan, and Somayajulu 2017; Bosdriesz et al. 2018; Gampfer 2018) suggested how digital technologies can improve the modernisation of cities via big data. To gain benefits that may lead to viable services in cities, a transformation of intra- and inter-urban activities is needed and often even supported by the deployment of innovative digital technologies (Heilig, Lalla-Ruiz, and Voß 2017). Therefore, digitalisation is pushing urban development and provides opportunities to improve productivity, efficiency and sustainability of city activities.

Currently, digital transformation in cities is strongly focused on implementing novel digital technologies to better control, monitor and measure urban operations, for example using real-time data for decision making and predicting future services (Heilig, Lalla-Ruiz, and Voß 2017; Lorincz, Capone, and Wu 2019). Although previous developments have resulted to a high degree of automation and digitalisation, especially in services provided by municipalities, there is still considerable need for improvement (Bosdriesz et al. 2018). Specially, in achieving better integration of existing data sources and information systems to improve management of urban services (Roedder et al. 2016). Given this perspective, digital transformation can create an integrated system of actors, stakeholders, and assets where citizens can exchange and communicate data within systems to facilitate decision-making processes (Bertola and Teunissen 2018).

Understanding the environmental, social, technical and economic implications of urban operations is the key for municipalities to unlock opportunities in making cities smarter (Gampfer 2018; Jnr 2020). At the same time, the role of digital transformation is important for cities to improve smart services. Accordingly, digital transformation has been targeted by municipalities as a goal towards achieving a sustainable future. But cities face considerable challenges with technological development in seeing through the complexity involved in transforming urban services (Grab and Ilie 2019). Similarly, the main challenges lie in the need for cities to develop platform-based ecosystems that breaks system silos (Dapp 2017). Therefore, there is need to transcend traditional silos in order to create new paths interlinking systems software and hardware (Vobugari, Srinivasan, and Somayajulu 2017). By addressing complexities and achieving optimum integration of cities systems can be linked into the value network of digital

ecosystems that enables processed data produced from other sources to be seamlessly integrated to provide value added services to citizens (Dapp 2017).

### 4.2. Phases of digital transformation in smart city domain

The on-going transition of economies and societies towards different institutional paradigms deeply managed by digital technologies is at the epic centre of existing debates, involving researchers and ranging from science, technology to humanities (Vobugari, Srinivasan, and Somayajulu 2017). Digital transformation is a means by which enterprise initiates changes in their business models and ecosystem by leveraging digital capabilities and technologies. It is the key to survive in today's emerging world as innovation continues to increase (Gampfer 2018). Digital transformation in urban environment refers to the adoption of technologies, and its abilities to digitise city's assets (Kempegowda and Chaczko 2018). Digital transformation will expand and augment the opportunities for cities to create new services and economic value. But the leading question for cities regarding this transformation is where and how municipalities can achieve these digital technologies in such a way that improves their business models (Agrawal, Narain, and Ullah 2019). The goal of digital transformation is to make information, product offerings, and business procedures available in digital form via IT based applications.

More precisely, in the context of this study digital transformation refers to a broader approach of transforming cities on different levels (e.g. people, governance, technology, strategy, culture, leadership, etc.) by utilising digital concepts and technologies (Heilig, Lalla-Ruiz, and Voß 2017). The source for all stages of digital transformation is the digitisation of analog sources, for instance, the change of paper documents into digital documents or the measurement of CO2 emission on the environment translated and represented into digital signals by deploying sensors. The integration improves information exchange in order to bridge system silos and support business-IT alignment (Heilig, Lalla-Ruiz, and Voß 2017). Cities adopt digital transformation in an effort to decrease costs and become more responsive to citizens demands (Roedder et al. 2016). While the literature on digital transformation offers clarity on adoption, there are fewer studies that investigated digital transformation in the context of smart cities. However, at the moment, only fewer studies (Vobugari, Srinivasan, and Somayajulu 2017; Bosdriesz et al. 2018; Gampfer 2018) has explored the phases of digital transformation in urban environment (Mendhurwar and Mishra 2019). Thus, this section resolves this gap in the literature.

Accordingly, digital transformations comprise of three phases which includes digitisation, digitalisation, and digitalisation as seen in Figure 5.

Figure 5 shows the phases of digital transformation in smart cities, each of the phase is discussed below;

#### 4.2.1. Digitisation

Digits '0' or '1' referred to signal or data are called Digital or Digitisation. Thus, digitisation is the procedure of representing information as '0' or '1' that is utilised by computers for storage, processing and transmission as information (Boratyńska 2019). Digitisation is also referred to as change of analog task to digital operations or can be conceptualised as the integration of IT to facilitate existing tasks, and

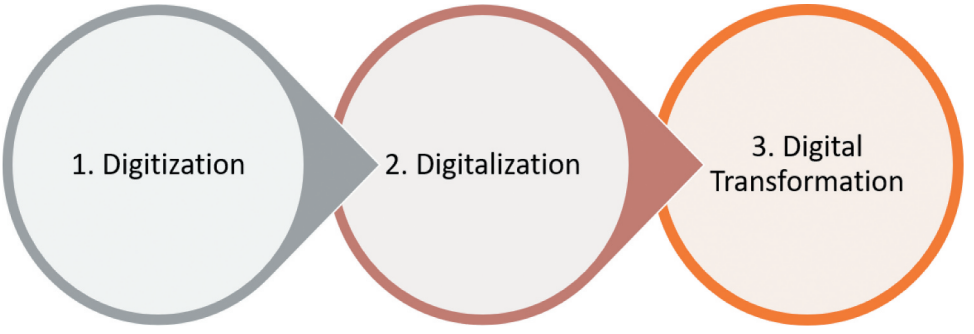


**Figure 5.** Phases of digital transformation in smart cities.

generally, as the enabler or development of cost-efficient resource configurations utilising IT (Verhoef et al. 2019; Khanra, Dhir, and Mäntymäki 2020). In summary, digitisation defines the process of converting information from analog to digital which can results to changes in existing business model to provide value to stakeholders (Heilig, Lalla-Ruiz, and Voß 2017; Boratyńska 2019).

### *4.2.2. Digitalisation*

Digitalisation refers to a socio-technical method of adopting digitising techniques to improve social and institutional contexts (Seth et al. 2020). Digitalisation defines how IT or digital technologies can be deployed to change existing municipality's processes. In digitalisation, IT serves as the main enabler provide new smart city development possibilities by changing current urban processes such as transportation, health, education, governance, energy, waste management, etc. (Verhoef et al. 2019). Through digitalisation cities apply digital technologies to optimise existing urban processes by achieving a more resourceful coordination between smart services, and/or by creating additional citizen value through improving services provided (Talwar et al. 2020). Hence, digitalisation not only focused on cost savings, but also entails process developments that improve citizens experiences (Verhoef et al. 2019).

### *4.2.3. Digital transformation*

As previously mentioned, digital transformation mainly refers to the required transformations driving the digitalisation based on a digital policy (Bertola and Teunissen 2018). Digital transformation is the most pervasive stage and defines urban-wide change that results to the actualisation of new business models by implementing smart service logic to create and capture value (Verhoef et al. 2019). Digital transformation impacts the whole city (both citizens and stakeholders), and the ways city operations are operated and goes beyond digitalisation by changing simple urban processes and tasks (Caponio et al. 2015). It reorganises the value creation process or business logic employed by the city (Verhoef et al. 2019).

The phases of digital changes towards digital transformation in smart cities have significant strategic imperatives for municipalities as seen in Table 2.

**Table 2.** The phases of digital changes towards digital transformation in smart cities.

| Phase | Cases | Digital Resources | Organisational Structure | Digital Growth Initiatives | Metrics | Targets |
|---|---|---|---|---|---|---|
| Digitisation | Automated tasks and routines. Conversion of analog data into digital information. | Digital assets. | Standard top-down system. | IS penetration, service development, and IS development. | Conventional KPIs such as Cost-to-serve, Return on Investment (ROI), Return on assets (ROA). | Cost reduction, More effective usage of natural resources for current activities. |
| Digitalisation | Use of artificial intelligence for smart urban services. Inclusion of digital components to service or product offering. Deployment of digital dissemination and communication mediums. | Digital assets, digital agility and digital networking ability. | Dispersed and agile components. | IS penetration, IS development, service development, IS-based products penetration, and systems co-creation. | Conventional and digital KPIs comprising of citizen experience, unique and active clients/stakeholders. | Cost decrease and increase in revenues for more efficient smart services via IS process re-engineering for better citizens experience. |
| Digital transformation | Adoption of new business models such as digital platforms, product-as-a-service, and mainly data driven business models. | Digital assets, digital agility, digital networking ability and big data analytics integration. | Isolated units with flexible management forms, internalisation of IS and analytical functional units. | IS penetration, IS development, service development, IS-based products penetration, systems co-creation, and platform change. | Digital KPIs which includes digital IS increase drive, and sentiment co-creator. | Innovative cost-revenue model for reconfiguration of city assets to deploy new business models. |

Table 2 shows the strategic requirements according to phases of digital transformation in smart cities (Verhoef et al. 2019). Likewise, Table 3 depicts the phases of digital transformation and descriptions (Heilig, Lalla-Ruiz, and Voß 2017). The description defines how each phase from digitisation to digitalisation and then to digital transformation can be achieved in smart cities.

### 4.3. Enterprise architecture towards digital transformation in smart cities

This sub-section reviews the significance of EA towards digital transformation in smart cities by discussing on smart city, eco-system and enterprise architecture, and significance of EA for digital transformation.

#### 4.3.1. Smart city, eco-system and enterprise architecture

As city systems converge, eco-systems that cut across multiple enterprises, functions and stakeholders will emerge to enable new and persuasive experiences (Wu et al. 2018). An eco-system refers to a complex web of symbiotic enterprises and relationships directed towards the allocation and creation of business value (Zimmermann et al. 2016). Eco-systems mask functional complexities typically cutting across multiple domains providing a basis for new, seamless users experiences (Berman and Marshall 2014). A city comprises of an eco-system of stakeholders that has a common set of goals (Anthony Jnr 2020b). According to Goerzig and Bauernhansl (2018) an eco-system is a self-adjusting and self-containing systems of loosely linked actors that mutually create value. These actors or stakeholders in an eco-system comprise of enterprises that provide services enabled through systems that have architecture. Thus, an enterprise is defined as a set of different

**Table 3.** The phases of digital transformation and descriptions.

| Phase | Description |
|---|---|
| Digitisation | • Development of methods and tools for exploring the collection of data in order to improve operational, tactical, and strategic decision making.<br>• Information dissemination between citizens and stakeholders for strategic partnerships.<br>• Creates active participation of citizens to facilitate more accurate data flows for service optimisation.<br>• Implement new tools to process to analyse data to prevent information overload for scalability. |
| Digitalisation | • Deploying cloud computing to enable city scale up or down of IT infrastructure to better fit the dynamic requirements of the city.<br>• Provide real-time information sharing to support collaborations and increasing citizens awareness of environmental impacts.<br>• Provide real-time contextual information for more efficient collaboration and coordination between urban community.<br>• Deploy data-driven decision making systems for valuable information flows and efficient urban operations. |
| Digital transformation | • Installation of actuators and sensors to improve control and management of urban infrastructure and equipment as well as transport vehicles during transit (e.g. Electric Vehicles (EV)).<br>• Assessment of environmental effects from urban infrastructures.<br>• Integration of city and external IT systems in a scalable cloud environment to facilitate constant flow of pertinent information.<br>• Enhancement of the accessibility of data by aiding different devices, installing wireless network access, and mounting information services (e.g. self-service citizens registration services, electronic road traffic IS).<br>• Deploy the potentials of growing velocity and growth of big data for improved decision making.<br>• Improve accuracy and availability of contextual data to improve the coordination between stakeholders and timely initiate remedial actions in case of system errors. |

and distributed areas that aim to achieve pre-determined goals (Zimmermann et al. 2016; Khisro and Sundberg 2018).

Furthermore, an architecture refers to an artefact developed by a human being, that has some purpose, usefulness, and meaning. Irrespective of the discipline or domain, architecture provides a model for solving a problem (Kempegowda and Chaczko 2018). The ISO defined an architecture as the fundamental structure of a system, based on its components, relationships, environment and the principles maintaining its design and evolution (ISO 2011). This definition can be adopted to smart cities by viewing a city as a system (Gampfer 2018). Enterprise and architecture as EA comprise of resources that are necessary for information dissemination and task coordination. EA in city context comprises of a set of models, principles and methods that help cities plan, design and realise its sustainability goals in relation to municipal business processes and information systems (Babar and Yu 2015). Centrally, EA aims to create transparency by documenting the actual state of city systems thus giving city administrators the control over complexity of information systems and processes.

EA aims to align IT with the goals and mission of the business sector of the municipality. EA ensures the city's objectives and goals related to IT are addressed in a holistic way (Zimmermann et al. 2018). To be successfully employed for smart city development, EA needs to be woven into the city's culture and not addressed as a closed scope venture. The value of EA is significantly enhanced when it is progressively embedded into the municipality's daily cycle. Besides, EA can be seen as a journey and not a project as it evolves over time and needs to maintain the flexibility needed to adjust to strategy shifts and emerging technological innovations conditions (Babar and Yu 2015). EA frameworks have been developed to manage the progressive complexity of change and innovation facilitating IT and business communication based on a common structure, process and language. EA also entails the as-is and to-be conditions, as well as the transition plan to be addressed in cities (Aliee, Kashfi, and Farahani 2019).

EA contributes to address complexity issues in information systems deployed in cities (Gampfer 2018; Saint-Louis, Morency, and Lapalme 2019). EA supports to control and conserve city's most stable systems transferring strategies to actual daily implementation. Importantly, EA connects stakeholders of diverse fields together to create solutions and services that are understood by all of them. Although, EA has the term enterprise it is mainly rooted in IT. Despite this, the application of EA in smart city is barely noticed in research (Goerzig and Bauernhansl 2018). EA can be utilised to provide a complete description of smart city by describing the important business and IT artefacts and their relationship (Zimmermann et al. 2016). With the advent of smart cities, the need for developing complex information systems was intensified. Also, due to development of technology in different aspects and their implementation in cities, responsiveness of EA is critical for the effectiveness of municipalities (Aliee, Kashfi, and Farahani 2019).

#### *4.3.2. Significance of enterprise architecture for digital transformation*

In the early days of technology, computing basically automated manual operations with greater productivity. As technology advanced, innovations enabled new processes and capabilities in society driven by IT. Progressively, IT transformed business but was not well aligned with business strategies (Oracle 2009). This inadequate alignment resulted in significant loss of resources and unexploited opportunities has placed enterprises in

competitive disadvantage in emerging market. In order to align business strategies with IT, a new approach for managing IT was developed termed as enterprise architecture (Oracle 2009; Saint-Louis and Lapalme 2018). Just as architecture provides blueprint or design for constructing buildings, EA can provides a blueprint and roadmap for aligning IT with city's business strategy. EA provides a guide to direct the transformation and evolution of cities with technology. This in turn makes IT a more tactical asset for successfully implementing a modern business development strategy (Oracle 2009). Accordingly, EA typically produces deliverables which include current state and future state reference model required to execute planned city initiatives.

EA also identifies deficits of current state in terms of its capability to support the strategies and objectives of municipality. EA provides an architecture roadmap to define the procedures required to migrate from the current state to future state (Oracle 2009). EA involves municipality addressing business requirements through architecture that facilitates to integrates systems needed to realise city's business objectives. EA ensures that architecture utilised by municipality is flexible to support the changing business model impacted by technology and evolving citizens expectation. EA is a field that holistically and proactively leads city's responses to disruptive forces (Kempegowda and Chaczko 2018). This is accomplished by identifying and analysing the implementation of changed towards the desired business vision and goals (Bhatt, Ghuman, and Dhir 2020). EA supports to identify business processes that are common and sharable across the city, optimise business efficiency and decrease operational cost (Jnr et al. 2020b). EA supports the changing business models and needs, provide improve service to citizens and improve service productivity (Kempegowda and Chaczko 2018).

EA facilitates digital transformation as a fundamental changing process initiated for competitive advantages through the development of IT for value creation. EA in digital transformation of cities aids municipalities to achieve clear transformation strategy and vision for stakeholders (Goerzig and Bauernhansl 2018; Jnr et al. 2020b). EA provides agility and flexibility in business and IT systems for digitisation of services and products in cities by proving close alignment of digital technologies and business models for smart solutions and strategies (Zimmermann et al. 2016). The digital ecosystem is an integration of disruptive technology that is constantly evolving (Kempegowda and Chaczko 2018). According to Kempegowda and Chaczko (2018) EA approach can contribute to digital transformation ecosystem by increasing the success rate of smart cities. In this study EA is integrated with digital transformations in smart cities to provide integral understanding and support of integrating different systems and services. The main motivation of this study is to extend EA approaches to attain adaptive and flexible digitisation of smart services.

### 4.4. Related works

During the years, a few studies has employed EA and/or digital transformation. Table 4 reviews studies that have adopted EA and/or digital transformation to improve services provided to citizens and stakeholders.

**Table 4.** Prior studies that employed EA and/or digital transformation.

| Authors and Contribution | Study Purpose | Components | Issue(s) Addressed | Technologies Deployed | Methodology | Context |
|---|---|---|---|---|---|---|
| Hämäläinen (2020) developed a framework for digital transformation smart city design. | Aimed to promote the governance and sustainability of smart city initiatives. | Strategy, technology, stakeholders and governance. | Smart city design | Data and digital technologies. | Data was collected from 7 participants using semi-structured interview. | Digital transformation of smart cities. |
| Akhmedova and Vavilonskaya (2019) discussed digital transformation of cities. | Intended to address issues related to the medium of innovative technologies deployment in city structuring. | Information hub, intellectual objects, intellectual objects, and information forms and details. | Intellectualisation in smart cities | IoT | Literature review | Digital transformation of smart cities. |
| Aliee, Kashfi, and Farahani (2019) investigated the evolving EA based on a digital transformation viewpoint. | Aimed to address the primary issue of generalisation of EA approach evolving. | Activities, process, working system, functions, business, eco-system and international community. | Generalisation of this evolving approach to EA. | IoT | Literature review | EA and digital transformation in Industry 4.0. |
| Grab and Ilie (2019) examined innovation management for smart cities digital transformation. | Focused to identify main components of innovation management for digital evolution. | Initiate, innovate, instate and integrate. | Digital transformation challenges. | Digital technologies | Literature review | Digital transformation of smart cities. |
| Okrepilov, Kuzmina, and Kuznetsov (2019) examined quality economics tools for sustainable development of smart cities based on digital transformation. | Focused to provide tools as a mechanism for addressing national economy development for digital transformation. | Standardisation, metrology, quality control and sustainable development. | Quality economics | ISO 37120:2014 standard | Literature review | Digital transformation of smart cities. |
| Tomičić Pupek, Pihir, and Tomičić Furjan (2019) explored smart city initiatives in the area of digital transformation. | Focused to specify key factors in most smart city initiatives related to digital transformation. | Services, scope and technologies | Empowering social and collaboration interactions | IoT and big data | Literature review | Digital transformation of smart cities. |
| Boban and Weber (2018) explored digital transformation from smart to intelligent cities. | Aimed to provide a framework to outline IoT, legal and regulatory issues in smart cities. | Economy, people, management, mobility, environment and quality of life. | Legal and regulatory General Data Protection Regulation (GDPR) issues | IoT | Literature review | Digital transformation of smart cities. |

(*Continued*)

**Table 4.** (Continued).

| Authors and Contribution | Study Purpose | Components | Issue(s) Addressed | Technologies Deployed | Methodology | Context |
|---|---|---|---|---|---|---|
| Gampfer (2018) researched how to manage complexity of digital transformation with EA. | Aimed to examine how EA can be effectively practiced aiding digital transformation. | Current state of EA and future state of EA. | Complexity | Cloud computing | Conceptual | EA and digital transformation in Enterprise. |
| Goerzig and Bauernhansl (2018) examined EA for the digital transformation in small and medium-sized enterprises. | Intended to provide the basics for developing a method for holistic planning of digital transformation in enterprises. | Initial point, change in context, and result. | Alignment of the internal IT Infrastrcuture. | Digital technology application | Literature review | EA and digital transformation in Enterprise. |
| Kempegowda and Chaczko (2018) deployed industry 4.0 with EA for successful digital transformation. | Aimed to explore how digital ecosystem and EA practice will aid digital transformation. | Business, application, data, technology and infrastructure | Successful digital transformation. | IoT, cloud, and big data. | Literature review | EA and digital transformation in Enterprise. |
| Zimmermann et al. (2018) explored the evolution of EA for digital transformation | Aimed to defined value-oriented mappings between digital business models, digital strategies, and an enhanced digital EA. | Digital strategy, value perspective, service perspective and digital EA. | Model complexities and provide microservices. | IoT | Literature review | EA and digital transformation for smart services. |
| Bondar et al. (2017) deploy agile digital transformation of system-of-systems architecture (SoS) models based on Zachman framework. | Reviewed various architecture frameworks that can be utilised for application on SoS architecture. | Scope, business, system technology, detail representations and functioning enterprise. | Complex dependencies and development of SoS architecture. | Servers, TCP/IP, database, firewall, and systems. | Agent-based model simulation SysML and UML. | EA and digital transformation for collaborative engineering services. |
| Vobugari, Srinivasan, and Somayajulu (2017) proposed a roadmap for designing effective complex EA in digital transformation. | Attempted to provide industry best practices for digital transformation grounded on experience-based. | Business, application, data and technology architecture. | EA complexity | SQL or NoSQL database | Conceptual | EA and digital transformation in Multinational Corporation. |
| Roedder et al. (2016) studied smart data analytics and digital transformation to enable developments. | Aided digital transformation, application development based on concrete use case example. | Smart data technologies, business transformation and enabling technologies. | Adaptiveness. | Sensors | Literature review | Digital transformation of smart cities. |

(*Continued*)

**Table 4.** (Continued).

| Authors and Contribution | Study Purpose | Components | Issue(s) Addressed | Technologies Deployed | Methodology | Context |
|---|---|---|---|---|---|---|
| Zimmermann et al. (2016) examined digital transformations of IT and business. | Aimed to support flexibility and agile transformations for businesses through adaptation and evolution of digital EA. | Business & systems monitoring services, information services for enterprise data and configuration of application systems. | Adaptiveness. | Adaptable digital enterprise architectures and service-oriented information systems. | Conceptual | EA and digital transformation in Enterprise. |
| Babar and Yu (2015) studied EA in the age of digital transformation. | Aimed to improve the scope of EA modelling to include phases of dynamics that exist within any enterprise. | Social, contextual, process and technological level. | Adaptiveness. | Real-time analytics from IoT. | Conceptual | Digital transformation of enterprise. |

#### 4.4.1. Gaps and limitations of prior literature

Findings from Table 4 review studies that employed EA and/or digital transformation in cities or enterprise. The review suggests that none of the studies employed EA to addressed system integration and complexity of digital transformation in smart cities. Hence there is need to address this short coming. Therefore, this study contributes to existing knowledge by employing EA approach to digital transformation of smart cities. Moreover, EA is adopted to support alignment between the strategic sustainability goals of cities and IT that supports smart services provided to citizens (Zimmermann et al. 2016), which is not fully addressed in prior studies. Hence, EA is employed in this current study as an approach to addressed system integration and complexity issues faced during digital transformation of cities into smart cities.

### 4.5. Contribution of EA towards digital transformation in smart cities

This sub-section shows the contribution of EA for digital transformation in smart cities by reviewing existing EA frameworks that can be employed for digital transformation in smart cities. Furthermore, the applicability of the Oracle EA framework for digital transformation in smart cities is demonstrated based on Electric Mobility as A Service (eMaaS) in smart city.

#### 4.5.1. Review of prior EA frameworks

Designing EA from beginning can be a tedious task, so EA frameworks were designed to simplify the procedure and guide IS designers or architect through smart system architecture development. EA framework provides templates, processes, standards, best practices and tools to facilitate creation of the EA models. Utilising EA framework streamlines the process for designing and managing architectures at all levels and supports municipalities to leverage the value of EA best practices. Presently, there are a number of EA frameworks aimed at addressing the basic challenge of aligning, assessing and organising technical requirements with business strategies. The Department of Defence Architecture Framework (DoDAF) is one of the EA frameworks applicable to digitally transform smart cities. It is a well-defined and sophisticated framework with three views. Although, DoDAF is grounded on three main views, a fourth view referred to as 'all view' is included to provide connection between the views by employing a dictionary to define specific terms to provide summarised, or contextual information. The requirements of each views are detailed and structurally described (Bondar et al. 2017).

DoDAF provides guidance and rules for consistency descriptions in achieving final products. Thus, ensuring that a common term is utilised for comparing, and integrating different systems, as well as systems of systems to achieve interoperability and interaction of systems. Ministry of Defence Architecture Framework (MODAF) is an extension of DoDAF that includes two more views, acquisition view and strategic view. The strategic view aims to support the capability management operations. Another EA framework is The Open Group Architecture Framework (TOGAF) Architecture Development Method (ADM) which is flexible and can be used in combination with other EA framework (The Open Group 2003). The TOGAF ADM is developed to support customisation for usage. The TOGAF ADM can be used as a guide in designing enterprise architecture. The TOGAF ADM allows an individual enterprise such as a city to choose or modify any part of the process

as needed. The ADM employs a generic approach for architecture development and designed to address most organisational and system requirements. TOGAF can be adopted to provide detailed reference on enterprise architecture which includes business, data, application and technology layers.

Gartner framework is another EA which includes architecting, business strategy, current-state architecture, environmental trends, governing and managing. Gartner framework provide cities with a logical method to develop an EA, it employs a multiphase, nonlinear, and iterative model, that represents synthesis and key features of best practices of how the most effective enterprises have deployed and sustained their EA. Gartner framework is reliable, and vendor-neutral, thus municipalities can choose to adopt it with another EA framework. The Federal Enterprise Architecture Framework (FEAF) establish the basis for initiating the behaviours and rules of an organisation (Council 2001). It provides principles that govern the implementation of the EA process. It is divided into business, applications, data and technology layers. FEAF aims to facilitate all US federal agency Chief Information Officers (CIOs) to design, develop, and implement an integrated architecture to exploit the value and reduce risks related to IT projects. Also, FEAF includes all necessary initiatives needed to design an EA and is suitable for more complex enterprises.

Additionally, the Zachman Framework is one of the first EA designed to explore the uncertainty, complexity and normativity of societal problems (Zachman 1999). It focuses on developing views rather than based on a methodology or process for the management of enterprise (Bondar et al. 2017). The Industrial Data Space Reference Architecture Model (IDS-RAM) provides the foundation for achieving smart services and innovative cross-enterprise operation, while concurrently ensuring that data sovereignty is deployed for data owners. Additionally, IDS-RAM is based on a reference architecture model which provides trusted and secure data exchange in enterprise ecosystems. The IDS-RAM comprises of business, functional, process, information, system layers, security, certification and governance.

The Generalised Enterprise Reference Architecture and Methodology (GERAM) entails systems and models required to implement and maintain single, virtual, extended or integrated cities. The goal of GERAM is to design and maintain the entire city eco-system by providing data while supporting city to identifying overlaps and adding benefits. The GERAM EA comprises of identification, concept, requirements, design, implementation, operation and decommission. The Oracle Enterprise Architecture Framework (OEAF) comprises of a collection of valuable solution architecture artefacts that enables Oracle's services and products. OEAF was proposed based on TOGAF, FEAF and Gartner framework to provide efficient, IT business-driven model in helping stakeholders align IT and business initiatives (Oracle 2009). OEAF components comprises of business, application, information, technology layers, as well as EA repository, governance, people, process and tools (Oracle 2009).

#### *4.5.2. Enterprise architecture in digital transformation for smarter cities*

In this study the oracle enterprise architecture framework is employed in digital transformation of smart cities. The OEAF offers a practical approach that provide the foundation for agile city architecture capabilities in mapping IT implementation to business requirements (Oracle 2009). OEAF is adopted in this study as it addresses unnecessary rigid

structures and complexities associated in digital transformation of smart cities. OEAF layers provide the appropriate information needed to achieve the objectives of making cities smarter via digital transformation. It avoids time consuming processes and supports integration of components to be deployed in parallel. OEAF can be deployed to effectively create an architecture roadmap for achieving smart city-driven smart services for digital transformations, as such is adopted in this study as the selected EA to be infused for digital transformation of smart cities. As previously stated, The OEAF comprises of seven main components as seen in Figure 6.

Figure 6 shows the OEAF components and Figure 7 summaries the definition of OEAF components. Each of the layers as seen in Figure 6 is discussed below.

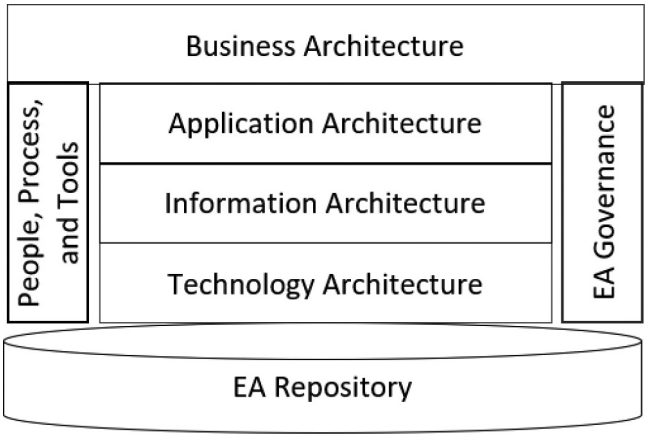


**Figure 6.** Oracle enterprise architecture framework components.

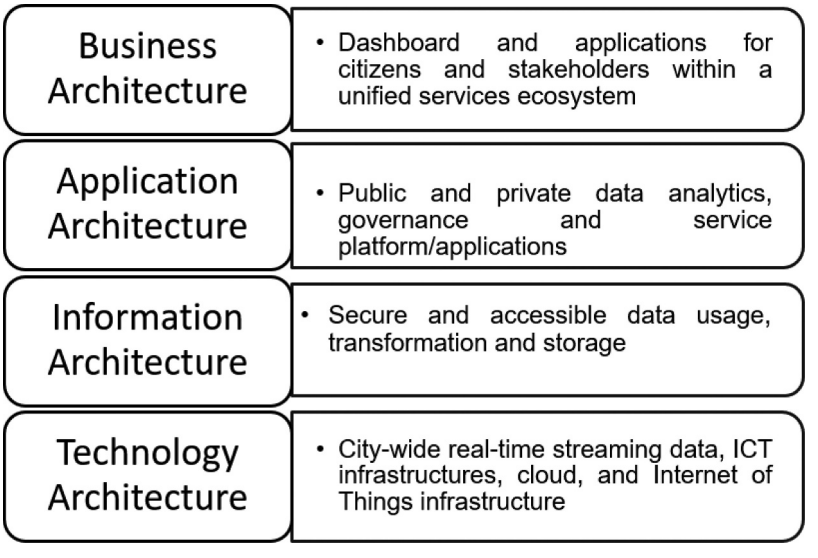


**Figure 7.** Definition of the Oracle enterprise architecture framework components.

- **Business Architecture**

The business architecture aligns city's operating model, objectives, and strategies with IT. This layer creates a business case for IT transformations by providing a business-centric view of the enterprises that provides services in the city from a functional perspective. It entails how systems and processes are centralised and decentralised across smart services provided by the city (Oracle 2009). Thus, business architecture entails high-level abstraction of services.

- **Application Architecture**

The application architecture provides application services centric view of systems that ties business functions and smart services to application components alignment (Atat et al. 2018). The application architecture encompasses applications that process, utilise and transform processed data, analysed data and third-party data (for improvement of smart services or analytics) sources into useful information (Wu et al. 2016; Anthony and Petersen 2019). The application architecture's is based on the business strategy, standards and scope (Oracle 2009).

- **Information Architecture**

The information architecture describes the components required to manage data across the city. it also includes the sharing of data to the citizens and stakeholders to achieve city's objectives as specified in the business architecture such as providing value added services to citizens. The information architecture provides data-centric and information view of the city, focusing on vital data assets that are utilised to accomplish critical business functionalities (Oracle 2009).

- **Technology Architecture**

The technology architecture describes the underlying infrastructures that supports business, application, and information architectures. The technology architecture comprises of hardware and software infrastructure deploy to provide smart services to citizens and stakeholders in cities (Oracle 2009). It also comprises of sensors and metering devices that generates real-time data and cloud infrastructures that collects, process, analyses and stores collected data.

- **People, Process, and Tools**

This component specifies the people, processes and tools utilised to define EA and architecture solutions. Where people include individuals and teams from several perspectives who are chartered with EA responsibilities (architecture design, implementation, maintenance and governance). The process entails adherence and selection to a set of architectural developments that are personalised to guide architecture engagement through a medium that increases the chance of successful deployment and lessening resource expenditure. The tools include set of technologies and techniques that

accelerate the process of designing and managing EA (Oracle 2009). These comprises of modelling tools which are discussed in section 4.6.

- **EA Governance**

EA governance provides the processes and structure for implementing municipality's businesses objectives and strategy. The EA governance component can be utilised to guide digital transformation to ensure business is aligned with IT elements during digital transformations initiatives implementations. A successful EA governance component considers the people (individuals, teams, responsibilities, and roles of the governance board(s)), policies and processes (architecture lifecycle management, review cycles, change management, etc.), technology (infrastructure for implementing the policies and processes of EA governance), and financial (IT cost distribution, city funding models, smart service case tools to regular monitoring for return on investment, etc.) (Oracle 2009).

- **EA Repository**

The EA repository is an Oracle-based repository that contains architecture deliverables and artefacts that are developed and captured throughout the lifecycle of EA (Oracle 2009) for digital transformation in making cities smarter. The EA repository provides information defining the current state architecture and also contains a knowledgebase of principles, models and architecture references that define the desired target state of the architecture of making cities smarter.

An application of OEAF in digital transformation for Electric Mobility as A Service (eMaaS) in smart city is shown in Figure 8. The presented example is derived from prior

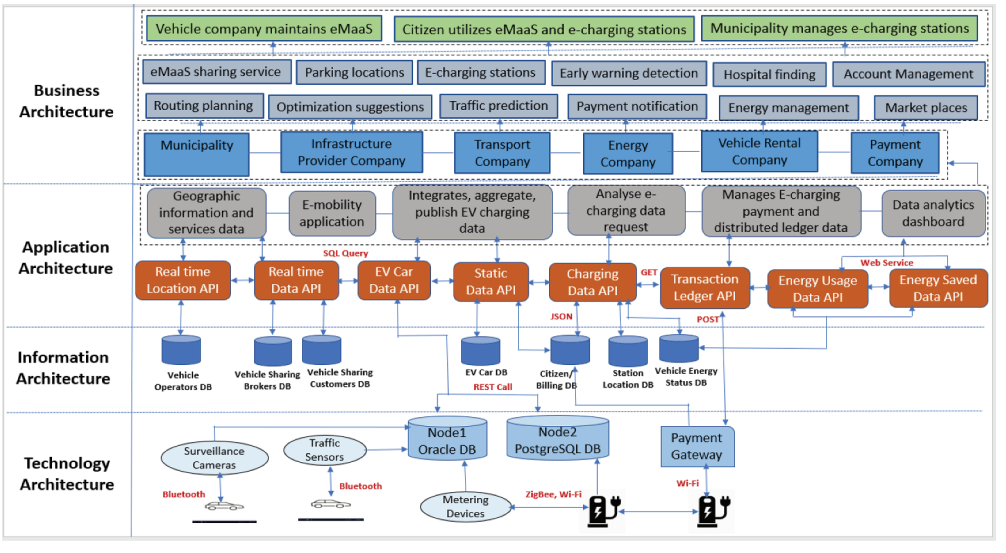


**Figure 8.** An application of OEAF in digital transformation for mobility in smart city.

studies (Anthony and Petersen 2019; Anthony Jnr 2020a; Jnr et al. 2020b) that employed EA to model eMaaS in smart cities.

Figure 8 depicts results of the applicability of OEAF in digital transformation for eMaaS in smart city. As seen in Figure 8 each of the layer of OEAF comprises of elements required to provide mobility services for citizens and stakeholders in smart city environment. The technology architecture comprises of the electric vehicles that is to be used by citizens which is connected using Bluetooth to surveillance cameras and traffic sensors, and charging stations connected to metering devices and payment gateway using ZigBee and W-Fi producing real-time data to be saved in non-relational database such as oracle DB and PostgreSQL DB. The information architecture comprises of several online data sources from mobility application as well as third party data from vehicle operator, vehicle sharing broker, vehicle sharing, EV car, citizen billing, station location and vehicle energy status databases.

The aforementioned data sources provide data to application architecture via Application Programming Interfaces (APIs) which includes real time location, real-time data, EV car data, charging data, transaction ledger, energy usage and energy saved APIs (Anthony Jnr 2020a). The retrieved data from the APIs provide data for geographic information service, electric-mobility application, integration, aggregation and publishing of EV charging data, virtualisation of charging data request, management of electric-charging payment and distributed ledger and data analytics dashboard for decision making support. Lastly, the business architecture illustrates the stakeholders which includes municipality, infrastructure company, transport company, energy company, vehicle rental company and payment company that collaborates to provide electric-mobility and other related services to citizens in improving transportation services and also making city mobility services smarter.

### 4.6. Current EA modelling tools applicable in smart cities

This sub-section discusses exiting EA modelling tools that can be deployed in smart city domain as seen in Figure 6 the OEAF 'People, Process, and Tools' component. EA tools can support cities to align business strategies with IT infrastructure goals. These tools aid to manage information related to city's current daily operations while helping municipalities plan roadmaps for digital transformation. They offer design module, reporting, collaboration, simulations, testing, etc. to help develop and deploy IT and business models for better smart services, reduced complexity and support IT systems integration deployed to provide services to citizens and stakeholders. Thus, '31' EA tools suitable for smart city context are described in Table 5.

Each of the EA tools are compared based on the following criteria which includes application portfolio management, capability mapping, idea management, project management, transformation road mapping, architecture governance, diagramming, modelling and simulation, risk assessment, and version control (Capterra 2020), as seen in Table 6. Where '1' equals yes and '0' equals no. The comparison reveals that RIS, ABACUS, BizzDesign, ADOIT, Dragon1, HOPEX and iServer EA tools performs well in terms of the comparison in relation to the other EA tools are can be used to support digital transformation in making cities smarter. Findings from the comparison a suggests that Archimate is the best EA tools based on it

**Table 5.** EA modelling tools applicable in smart city environment.

| EA Tools | Description |
|---|---|
| Sparx | Sparx systems enterprise architect offers novel visual modelling tool for planning, designing and reporting cooperative business architectures. It can also provide robust support for city-wide, cloud-oriented collaboration with a combined view of current state, deployment pathway and future state. It's mostly suitable in providing support for highly scalable, cloud-based EA. |
| IRIS | IRIS business architect is an affordable and reliable EA collaborative tool to create roadmaps from business strategic development to agile IT deployment. It's aligned to EA framework TOGAF and is simply customisable. IRIS offers rich modelling, design and maintaining functionalities that constantly reflect changes in the architecture, lessen risk and improve decision making. |
| ArchiMate | ArchiMate modelling language is an open source, cross-platform and independent EA standard that facilitates the description, analysis and visualisation of architecture across and within business domains. ArchiMate is an open standard provided by The Open Group and is implemented to be aligned with TOGAF. ArchiMate provides a low cost solution to cities who may wish to engage with EA framework such as TOGAF. ArchiMate supports stakeholders in assessing the impact of design changes and choices. ArchiMate fulfils the needs of most IS architects and has been designed to smartly provide key features required and is utilised worldwide. |
| AdaptiveGRC | AdaptiveGRC enterprise architect manager enables EA designer to integrate internal and external systems though a flexible and intuitive interface. This develops a full map of the city's enterprise information. It allows for tracking of data connections, regulatory policies through systems and also supports system risk profiling. |
| ABACUS | ABACUS was developed by Avolution for achieving a quick and powerful EA strategy. ABACUS supports digital business planning, collaboration, and analysis. It can create models and roadmaps in minutes, import centralise data and, execute algorithms to predict the results of strategies and provide visuals dashboards report. ABACUS is available as a cloud tool or as a free version. |
| GENESYS | GENESYS is an enterprise collaborative tool that provides context-driven modelling for systems engineering cases. GENESYS provides end-to-end model-based systems design capability, which goes beyond specifying requirements and risk management abilities in spreadsheets. Its capability to exports and imports from artefacts, generate DoDAF viewpoints and elements, and reporting is very helpful. |
| BiZZdesign | BiZZdesign enterprise studio is the collaborative business platform which offers indispensable guide in strategic business strategies. BizzDesign aims to address silos across different system for fastening the pace of change for project team members. It integrates architecture models, service design and analysis capabilities to stakeholders. It can aid to create insight for better informed decisions and enhances municipality's capabilities in being a smart city. |
| Centrify zero trust privilege | Centrify zero trust privilege is an EA tool that redefines legacy method to provide secure modern based cloud enterprise use cases. Centrify is more suitable for enforcing privilege to helps manage users privilege access by validating who is requesting data access and the context of the data request. Centrify is more suitable to serve IT operations, infrastructure and security of stakeholders throughout urban environment. |
| Insight-EA | Insight-EA is a powerful cloud tool focused on providing accelerated time to value and aligning IT, information to business strategy. It possesses the capability of supporting transformation related to application rationalization/optimisation, mergers/acquisitions, advanced information management and analytics. Insight-EA is suitable for large cities struggling with lack of alignment between IT Infrastrcuture and business initiatives typically stemming from city's, services and technical architecture. |
| Monosign | Monosign EA provides an identity and access management solution for cities, in effecting IT security. Thus, enterprises that provides smart services to more than 500 citizens are adopting or using Monosign EA for public or internal web applications such as cloud applications. It provides a flexible sign on service for about 30 different external and internal services suitable for smart cities. |
| Ardoq | Ardoq is a data-driven documentation tool with a focus on interconnecting IT and business area of cities. Ardoq provides an auto-generated visualisation that help cities understand cities operations in an appropriate way. This makes Ardoq a robust tool for managing unstructured data, something that is becoming needed at urban planning level. |
| ADOIT | ADOIT is an EA tool that provides management of teamwork. ADOIT mostly ideal for providing an information base for all stakeholders for the management of single IT process management. ADOIT provides detailed views and reports for quick and informed decisions on the impact of planned changes. |

(*Continued*)

**Table 5.** (Continued).

| EA Tools | Description |
|---|---|
| ALFABET | ALFABET is a collaborative system that links IT systems to their corresponding business functions supporting competitive transformation. |
| Cameo | Cameo EA is a tool with gap analysis capability mainly applied in defence based institutions. |
| Changepoint | EA is a social, simple, smart application that design visual, real-time map of cities IT systems to better understand complexities, dependencies, and impacts of relationships across city's business. With changepoint municipality can view the entire city landscape, so they can efficiently manage risk, and create innovation. |
| Dragon1 | Dragon1 employs cloud platform for EA teams to successfully collaborate and work. It supports stakeholders for decision-making to guide city-wide transformation. It helps create a holistic, and interactive visualisations for the current, future and envision state of city development. |
| Wijmo | Wijmo EA provides high-performance JavaScript interface controls for city applications developed on lightweight, high speed with zero dependencies. |
| dspConduct | dspConduct EA offers data management solution that can supports cities of all sizes to design, implement and monitor system processes utilising data collection and validation. |
| EAComposer | EAComposer EA is a cloud EA tool with a built-in secure database and visual modeller for storing your city system reports and analyses. |
| Enterprise Private Cloud (EPC) | EPC uniquely supports to achieve a city computation strategy such as in managing centralised big data analytics for smart application development and business intelligence. |
| System Architect | System Architect automate the design of data-driven maps for city's EA and systems inter-dependability. |
| Essential | Essential is an EA management tool that provides visualisation of city's business, people, processes, IT and data. It aids informed decision making based on data, supporting cost decrease, increased productivity, risk decrease and strategy delivery. Essential also provides open source and commercial solutions to address service needs of cities. |
| QPR enterprise architect | QPR enterprise architect offers solution with analytical capabilities and configurable modelling that align strategy between IT and business sectors. |
| HOPEX | HOPEX EA helps cities get an overview of risk, business, IT, and data on how they integrate to modernise, rationalise, or upgrade their city and IT systems. HOPEX tools allows to improve decision-making by reducing silos and improving collaboration. |
| IOA | IOA EA provides a cloud management solution that can aids cities with data management, information security and migration. |
| iServer | iServer is a robust EA tool with a dashboard and reporting capabilities for decision support and analysis that support and leverages existing city's investments using Microsoft technologies, such as Visio, SharePoint, Office and SQL Server to provide an easy to use environment for planning and deploying strategic change. |
| Capsifi's | Capsifi's is a cloud-oriented modelling tool for strategic planning and IT-business transformation execution. It provides integrated, dynamic business models that establish contextual relationships between different views of service innovation, transformation and delivery. It also provides dashboards for alignment, traceability and holistic insights to decrease risk and improve outcomes. |
| Keboola | Keboola is an analytics EA tool that supports cities combine, improve and publish data for project development. It supports entire data workflow, based on an extensible cloud environment that helps businesses to take full advantage of internal and third party data sources for data visualisation and business intelligence. |
| LeanIX | LeanIX EA offers a collaborative open, data-driven architecture management system to help cities adapt to the increase demands of digital services to reduce time to value delivery. |
| Modelio | Modelio modelling is an open source tool that supports EA and software development capacities. |
| Prolaborate | Prolaborate EA tool supports collaboration based on Sparx systems EA models to be seamlessly connected to efficiently engage non-EA stakeholders to review EA diagrams and support agility and transparency in creating IT and business alignment models. |

being free and open source and can be used for modelling IT and business components in providing smart services.

**Table 6.** Comparison of EA tools.

| EA Tools | Application Portfolio Management | Capability Mapping | Idea Management | Project Management | Transformation Road mapping | Architecture Governance | Diagramming | Modelling/ Simulation | Risk Assessment | Version Control |
|---|---|---|---|---|---|---|---|---|---|---|
| Sparx systems | 0 | 0 | 1 | 1 | 1 | 0 | 1 | 1 | 0 | 1 |
| RIS | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| ArchiMate | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 1 | 0 |
| AdaptiveGRC | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| ABACUS | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| GENESYS | 0 | 1 | 0 | 1 | 0 | 0 | 1 | 1 | 1 | 0 |
| BizzDesign | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Centrify | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 |
| Insight-EA | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 0 |
| Monosign | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| Ardoq | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| ADOIT | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| ALFABET | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| Cameo | 0 | 1 | 0 | 1 | 0 | 0 | 1 | 1 | 1 | 0 |
| Changepoint | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Dragon1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Wijmo | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| dspConduct | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| EAComposer | 1 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 1 | 0 |
| EPC | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 1 | 0 | 0 |
| System Architect | 1 | 1 | 0 | 0 | 1 | 0 | 1 | 1 | 0 | 0 |
| Essential | 1 | 1 | 1 | 0 | 1 | 1 | 0 | 1 | 1 | 0 |
| QPR | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| HOPEX | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| IOA | 0 | 1 | 0 | 1 | 1 | 1 | 0 | 1 | 0 | 0 |
| iServer | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Jalapeno | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 |
| Keboola | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 0 | 0 |
| LeanIX | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 0 | 1 | 1 |
| Modelio | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 1 | 0 | 1 |
| Prolaborate | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |

## 5. Implications of study

### 5.1. Theoretical implications

EA frameworks provide an approach that aid IS architects to focus on the architecture and not be tied down with artefacts and processes or creating their own EA process. Respectively, EA frameworks such as OEAF enhances return on city's investment via better deployment of municipality's strategy utilising IT, and more effective reuse of IT resources, leveraging technology to achieve new smart business strategies. Besides, the agile nature of EA frameworks supports continuous improvements to adjust changing societal needs and new technologies since EA uses industrial based system design terminology and concepts to leverages the best of IT capabilities in making cities smarter. Theoretically, this study employs Oracle enterprise application framework (OEAF) as an EA framework to support digital transformation in making cities smarter by provides significant value to municipalities in addressing complexities and system integration.

Additionally, OEAF helps for continuous alignment of IT components and business strategies to show the current-state architecture to relevant stakeholders in making cities smarter as seen in the modelled eMaaS case scenario presented in Figure 8. Policy makers in municipality can utilise EA for decision support to improve current city's business model and IT services. Furthermore, this research complements and extends prior studies (see Table 4) on EA and/or digital transformation by offering a more practical understanding of how IT components relates to business strategies to provide services. The deployment of EA framework (OEAF, see Figure 8) provides cities with a clear example of how data from different sources can be utilised and integrated to create added value services to citizens and stakeholders.

### 5.2. Practical implications

EA provides diagrammatical information to serve as foundation for both business and IT practitioners to understand business requirements and IT impacts in providing smart service in urban environment. EA approach for digital transformation provides a good foundation for reducing complexities and integrating systems required to provide smart services in cities. Thus, EA is seen as vital, especially in communicating corporate plans across the city and defining an extensive framework. In this study EA is suggested to improve digital transformation by addressing complexity and system integration issues. The presented EA framework (see Figure 8) for digital transformation offers guidance to city developers and planner's on how to improve urban services. This study provides valuable practical implications to practitioners and researchers to understand the role of EA for digital transformation in urban environment into real environmental, economic and social context. Therefore, this is one of the first studies that focuses on adopting EA and digital transformation in smart city domain.

Additionally, this research contribute to the current IS literature by introducing this new perspective for EA in digital transformations in urban context. Thus, findings from this study provides practical implications showing innovative pathways which are still unexplored. Besides, this study reveals that EA frameworks such as OEAF provides access to a set of tool sets, tailored architecture, best practices and reference architectures to

significantly lessen the time needed to develop urban-level architectures. Technically, findings from the modelled eMaaS case suggest that EA aids to visually depict all of city's systems in a common language that is understandable by citizens, businesses, municipalities, and technical experts to resolve issues such as misalignment, redundancy and inefficient resource usage faced in digital transformation of smart cities. The application of OEAF for mobility case scenario in smart cities provides recommendations to practitioners who are typically immersed into silos competences on how they can build new bridges among isolated IT system and interconnection within these systems, taking advantages of digital transformation potential.

## 6. Conclusion

This paper employed a systematic literature review on EA and digital transformation in smart cities. This paper contributes to the research on EA for digital transformation within smart cities to support actors in co-creating individual, organisational value, and societal well-being from business strategies and IT initiatives. Thus, this study is an answer for ongoing call for holistic and systematic IS methods to support environmental and human well-being in smart city domain. Moreover, EA is employed in this study to better support ICT architecture design, assessments, diagnostics, and monitoring for decision support, and optimisation of smart services. Increased complexities and lack of integration between systems leads to organisational barriers for stakeholder's collaboration within smart cities.

Accordingly, this study argue that EA and digital transformation concepts are useful artefacts to help overcome these setbacks. The findings from this study presents the importance of digital transformation in smart city domain, the phases of digital transformation in smart city domain and significance of EA towards digital transformation in smart cities. Besides, the findings reviewed prior studies that employed EA and/or digital transformation in cities or enterprise context and practically demonstrated how EA can contribute towards digital transformation in smart cities. Lastly, exiting EA modelling tools that can be deployed in smart city domain were discussed.

### *6.1. Research agenda*

The rapid growth of IT within the last decades has come along with the development of innovative systems, standards, and software programs that support and shape services provided by municipalities to its residents in several ways. On the one hand, cities nowadays have to deal with integrating different systems. This environment of ongoing technological change requires a transformation of urban processes, structures and strategies. Under the notions digital transformation was suggested to identify key aspects of such changes and provide support for city's business transformation. Digital transformation comprises a combination of business models and innovation. Digital transformation within the digital ecosystem aims at improving, creating and converting new solutions. Digital transformation entails innovation and transformation which employs digital technology and existing operational models to produce value. Digital technologies have the potential to transform significantly the way city operations are deployed. As seen in Figure 8, EA integrates and connects different systems and data sources to support the flexible

delivery of data to be used by applications provided from different businesses which collaborates to provide value to improve mobility related services to citizens. Municipalities can utilise the designed OEAF case scenario to overcome the technical integration problems in transportation sector as a means to achieve more 'smart' delivery of data-driven services supporting the digital transition and transformation to smart mobility.

### *6.2. Limitations and future works*

The limitation of the study is based on the fact that only secondary data from the literature were employed. Primary data was not collected to empirically validate the designed EA (OEAF case scenario) based on real data from a city. Further studies could be conducted by using real mobility data to validate the applicability of the EA framework for digital transformation of eMaaS in smart cities. Besides, EA can be employed by cities to assess their maturity level of different services provided and also provides guidelines on how to migrate from their present state to future state. Also, further work can involve developing a framework to assess the maturity of cities that adopts EA to digitalise their data driven services.

## Acknowledgements

This publication is a part of the +CityxChange smart city project under the Smart Cities and Communities topic that is funded by the European Union's Horizon 2020 Research and Innovation Programme under Grant Agreement No. 824260.

## Disclosure statement

No potential conflict of interest was reported by the author.

## Funding

This publication is a part of the +CityxChange smart city project under the Smart Cities and Communities topic that is funded by the European Union's Horizon 2020 Research and Innovation Programme under Grant Agreement No. 824260.

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