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RESEARCH PAPER

Concepts for Modeling Smart Cities

An ArchiMate Extension

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Abstract The rapid increase and adoption of new Information Technologies (IT) in Smart Cities make the provision of public services more efficient. However, various municipalities and cities deal with challenges to transform and digitize city services. Smart Cities have a high degree of complexity where offered city services must respond to the concerns and goals of multiple stakeholders. These city services must also involve diverse data sources, multi-domain applications, and heterogeneous systems and technologies. Enterprise Architecture (EA) is an instrument to deal with complexity in both private and public organizations. The paper defines the concepts for modeling Smart Cities in ArchiMate, guided by a design-oriented research approach. Particularly, the focus of this paper is on the concepts for modeling city services and underlying information systems which are added to the EA metamodel. The metamodel is demonstrated in a real-world case and validated by Smart City domain experts. The findings suggest that these concepts are essential to achieve the Smart City strategy (e.g., city goals and objectives), as well as to meet the needs of different city stakeholders. Furthermore, an extension mechanism allows addressing the alignment of business and IT in complex environments such as Smart Cities, by adjusting EA metamodels and notations. This can help cities to design, visualize, and communicate architecture decisions when managing the transformation and digitalization of public services.

Keywords Enterprise architecture · Enterprise modeling · Smart city · Service · Information · Alignment

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1 Introduction

The digital transformation of public services in Smart Cities takes advantage of the rapid progress in the development of IT capabilities (Zhuhadar et al. 2017). The public sector is enabled with the advance in IT solutions that make the provision of city services (e.g., air-quality service, health service, public-lighting service) more efficient. Citizens demand the enhancement of the quality of services from multiple domains (e.g., energy, mobility, buildings, etc.) where social, economic, sustainable, and technological changes are required (Singh et al. 2021; Neirotti et al. 2014). Smart Cities need to respond to this citizen-centric approach by offering cross-domain city services to increase their overall quality of life (Yeh 2017).

Moreover, city managers must be able to use a large amount of information to support decision-making and the optimal operation of cities in accordance with an integrated long-term strategic vision (Schleicher et al. 2016). Yet, there is not a structured approach in the context of Smart Cities to express such complexity and support strategic planning (Helfert et al. 2018). Cities can fail to deliver city services and systems aligned with city goals and objectives to respond to the needs of citizens.

Enterprise Architecture (EA) can be used to structure the digital transformation of public services and, consequently, manage complexity in Smart Cities (Ylinen and Pekkola 2019; Anthony Jnr 2021). Smart Cities can be viewed as urban enterprises, with strategic aspects, governance and innovation capabilities, and multidimensional issues (Mamkaitis et al. 2016; Bastidas et al. 2017). Public services transformation affects various aspects of these cities, including strategy, stakeholders, organizational structure, information systems, and technological infrastructure. Enterprise Architecture Management (EAM) is an established planning and governance approach to manage the change and address the alignment between those various aspects by adopting a comprehensive perspective on the overall architecture (Buckl et al. 2010; Ahlemann et al. 2012). Many researchers describe concepts and frameworks for EA and highlight its benefits such as strategy achievement, complexity management, and business and IT alignment (Shanks et al. 2018). Concepts, layers, and modeling tools of EA can provide an integrated approach to strategic planning and a guide to deliver desired services aligned with clearly defined city objectives.

A number of EAs for Smart Cities are proposed to face the challenges of implementing a digital transformation of public services (McGinley and Nakata 2015; Kakarontzas et al. 2014; Anthopoulos and Fitsilis 2014; Cox et al. 2016; Lnenicka et al. 2017; Petersen et al. 2019). These EAs for Smart Cities adopt traditional EA frameworks such as TOGAF (The Open Group 2018) and Zachman (Zachman 1987) to manage architecture complexity and describe architecture content. In particular, a multi-layered EA framework identifies the notion of city context and services as a reference on applying EA to Smart Environments (Pourzolfaghar and Helfert 2017; Pourzolfaghar et al. 2019). However, there is no specific focus on the concepts for expressing city services and the underlying information systems aligned to Smart City strategies (Helfert et al. 2018). Traditional concepts of EAM and modeling approaches are suitable for structuring an EA for Smart Cities, but not enough to meet specific requirements of this domain (Ahlers et al. 2019; Lnenicka et al. 2017). This lack of domain-specific concepts has resulted in Smart City solutions that do not provide city services to respond to the concerns and goals of stakeholders and meet the needs of citizens.

In this paper, we propose the concepts for modeling Smart Cities by extending ArchiMate. ArchiMate is a graphical modeling language for describing and visualizing EAs (The Open Group 2017). We focus specifically on the concepts to support the management of city services and their information systems aligned with city goals and objectives. The ArchiMate extension is used to design a solution for a waste management service in Netanya, an innovative Israeli Smart City. The waste management service is selected due to its relevance for Smart Cities in achieving the sustainable development goals (SDGs) and handling environmental problems that affect the quality of life for the citizens (Esmaeilian et al. 2018). The proposed concepts are validated by the Smart City domain experts of Netanya municipality and the Federation of Local Authorities in Israel. The results suggest that these concepts are essential to achieve the Smart City strategy, as well as to address the concerns of different stakeholders. The results can be used as a guideline for municipalities with similar Smart City initiatives, allowing the consideration of strategic aspects and various views of city services and enabling a general perspective on complex IT solutions. The main contributions of this paper are summarized below:

- First, this study builds an understanding of the different concepts (e.g., strategic, city service, and information systems concepts) for modeling Smart Cities to provide a coherent architecture description of this field.
- Second, this study provides design principles and features as abstract prescriptions for the design of modeling methods and tools for Smart Cities.
- Third, this study proposes an approach to extend ArchiMate for Smart Cities where domain-specific elements are required, thus expanding EA modeling capabilities into the context of Smart Cities.
- Fourth, this study demonstrates the application of the ArchiMate extension by designing a city service solution aligned with city goals and objectives to enhance the understanding of how to achieve desired outcomes.

The remainder of the paper is organized as follows: Section 2 introduces the background. Section 3 presents the research method. Section 4 details the design process. Section 5 presents the ArchiMate extension. Section 6 presents the demonstration of the artifact and Sect. 7 presents its evaluation. Section 8 discusses the proposed concepts and Sect. 9 concludes the paper.

2 Background: Enterprise Modeling Overview

Enterprise Architecture Management (EAM) is a management discipline to design and develop an organization according to its strategy and vision (Ahlemann et al. 2012). For this purpose, models and concepts are used to guide the structured development of Enterprise Architecture (EA). Enterprise modeling (EM) provides the techniques, languages, tools, and best practices for using EA models (Horkoff et al. 2018). EA models are tools of analysis, communication, and support that address enterprise transformation challenges (Silva et al. 2021). The Open Group Architecture Framework (TOGAF) is one key and widely accepted framework of EA, that proposes ArchiMate for modeling integrated EA models (The Open Group 2017). This language describes cross-layer dependencies, which contributes to support the business and IT alignment through a model-based approach (Lankhorst 2004).

ArchiMate is an EM language in which concepts and relationships play an essential role in creating coherent models to guide architecture implementation (Rurua et al. 2019). Graphical modeling languages specify modeling language aspects by graphical means (Bork et al. 2020). This specification comprises two different levels of formality, including the definition of the abstract and concrete syntax. The abstract syntax defines a set of modeling concepts and relationships between these concepts that must correspond with the concepts in the semantic domain. The concrete syntax specifies the notation and semantics of the modeling language. Notation refers to the graphical representation of syntactic concepts while semantics specify the meaning of them. Moody (2009) introduces a set of nine principles for designing cognitively effective visual notations and graphical qualities that contribute significantly to the communication and understanding by domain experts.

EM languages (e.g., ArchiMate, MEMO, ARIS, and other EM languages) have a high level of abstraction, which can lead to miss the representation of specific modeling scenarios (Lara et al. 2019). Domain-specific languages are created to solve this lack of specificity within a defined domain, by creating the vocabulary and notations to describe the domain (Pfeiffer 2007). Domain-specific modeling methods can allow to define domain-specific requirements and formalize them by means of conceptual modeling (Visic et al. 2015). ArchiMate is a standard language used to model any type of architecture. ArchiMate can be used to allow its specialization for the Smart City domain with the addition of concepts and relationships, and the modification of graphical notations.

3 Research Method

This paper follows a design science research approach and research method (Peffers et al. 2007) due to the relevance to the domain of information systems (IS). This study aims to define the concepts for modeling Smart Cities that can assist cities and municipalities to support the management of city services and their information systems. The design process is divided into four main phases: *identification and motivation of the problem, design and development of the artifact, demonstration of the artifact, and evaluation of the artifact*. EAs frameworks and concepts for Smart Cities are reviewed as part of the *problem identification*, see the introduction section.

The *design and development of the artifact* phase involves the definition of the concepts proposed based on a set of design requirements extracted from the literature. The search strategy follows a structured approach to determine the source material for the review (Webster and Watson 2002). An initial set of papers (57 journal articles) is selected by retrieving all the titles of the papers published by a relevant set of scientific journals on topics regarding Smart Cities and Information Systems management. The keywords used in the search process include smart city service(s), smart city information system(s), and smart city management. The most relevant papers are selected based on the title, abstract, and keywords terms. Followed by a backward and forward search, a set of 26 articles and 5 design requirements was iteratively refined and aggregated. The literature review results are further elaborated in Sect. 4.1. Appendix A details the literature review process conducted. The set of design requirements is used to develop design principles and from those derive design features, see Sect. 4.2. The design principles were formulated according to the approach proposed by (Chandra et al. 2015) for effective formulation. The design features are instantiated by extending the ArchiMate language, following a modeling method for domain-specific languages (Visic et al. 2015).

The *demonstration of the artifact* phase includes a case study to illustrate the realistic use of the artifact in Netanya municipality. A waste management city service is selected because of the importance of the link between waste management services and IS to enable stakeholders to develop environmentally urban planning systems. The data of the case study is collected by applying semi-structured interviews to the Smart City and digital domain manager and waste management process owner in Netanya. Internal documents and the official municipality website are also used to acquire more information on the service. The ArchiMate extension is used to design architecture models specific to the case study. The models are created in an iterative manner by asking the stakeholders for feedback on the resulting models.

The *evaluation of the artifact* consists in assessing the utility and quality of the artifact (Helfert et al. 2012) within the case study and the application of a semi-quantitative survey that is systematically judged by a group of domain experts of the Federation of Local Authorities in Israel.

4 Design Requirements of Smart Cities and Design Principles for a Metamodel Artifact

This paper proposes the concepts for modeling Smart Cities by extending an EA metamodel. The design process was an iterative process by asking the domain experts for feedback on the designed artifact and refining the artifact based on their feedback. This design builds on and benefits from our experience working on modeling public city services different cities. During the design phase, we formulated initial design requirements (DR) from literature and refined them in a process of discussion and reflection with domain experts. The design requirements were used to formulate design principles (DP) and from those derive appropriate design features (DF). Design features were used to guide the design and development of our metamodel extension. The concepts for modeling Smart Cities were validated and refined within 3 different iterations: (i) in the case study demonstration, see Sect. 6 (ii) during the evaluation within the case study, see Sect. 7.1 and (iii) in the evaluation with Smart City domain experts, see Sect. 7.2.

4.1 Design Requirements

This section presents the design requirements, focusing on the main characteristics to manage city services and their information systems. These design requirements are defined as generic requirements that the artifact (i.e., an EA metamodel) instantiated from this design should fulfill as described by Walls et al. (1992) and depicted by Baskerville and Pries-Heje (2010). Figure 1 illustrates the relationships between design requirements (DR), design principles (DP), and design features (DF). The identified design requirements are outlined as follows.

DR1: *It is required to provide dedicated concepts to manage Smart City application domains.*

The definition of Smart City application domains must start from the services design phase (Ma et al. 2016). Neirotti et al. (2014) propose a classification of domains and sub-domains based on the degree of importance of ICT as an enabler of Smart Cities. Each domain consists of a set of services, for example, the transport and mobility domain may include public transport services and emergency vehicle monitoring services. City managers are responsible for leading projects in such vertical domains that need the integration of services from the same or different domain (Michelucci et al. 2016). The seamless flow of information between cross-domain services can help to realize a horizontal flow of information between multiple stakeholders (Hefnawy et al. 2015). It is necessary to define the relationships between these domains and other concepts (e.g., city services, application services) to meet different requests from citizens (Cabrera and Clarke 2019).

DR2: *It is required to provide dedicated concepts to manage Smart City outcome measurement.*

Smart Cities aim to enhance urban efficiency by using ICT to provide enhanced services to citizens. Indicators should be established to monitor the progress towards desired smart city goals and detect stakeholder priorities (Loo and Tang 2019). These indicators reflect the level of intelligence, efficiency, and sustainability of cities (Al-Nasrawi et al. 2015). ISO37120 (2014) proposes standardized indicators for city services and quality of life to achieve sustainable development of cities. These indicators should reflect qualitative characteristics and quantitative data acquired from heterogeneous data sources (Zdraveski et al. 2017). It is necessary to offer a model representation of the indicators and their relationships with other concepts (e.g., domains, stakeholders and goals to which Smart Cities are moving).

DR3: *It is required to provide dedicated concepts to manage Smart City services and its relevant types.*

The public sector has shifted towards a service orientation paradigm (Bifulco et al. 2016; Pourzolfaghar and Helfert 2017). Three key features of services are considered crucial: functionality, behavior, and quality (Bouguettaya et al. 2017). Functionality refers to the operations offered by a service. City services and application services are specified according to the functionalities provided and the level of abstraction in Smart City architectures (Oktaria et al. 2017; Yeh 2017). Behavior reflects how service operations are invoked. Smart city services can be invoked via different application programming interfaces (APIs) such as web services to access a single data set or data aggregations (Nesi et al. 2016). Web services are a key technology in this domain and Smart City managers are required to select the most appropriate web services to obtain the desired service functionalities (Purohit and Kumar 2019). Quality of service will be discussed in the next requirement.

DR4: *It is required to provide dedicated concepts to manage the quality of Smart City services.*

Expressing the quality of service is needed to allow requesters to specify service quality expectations; providers to advertise quality levels that their services achieve;

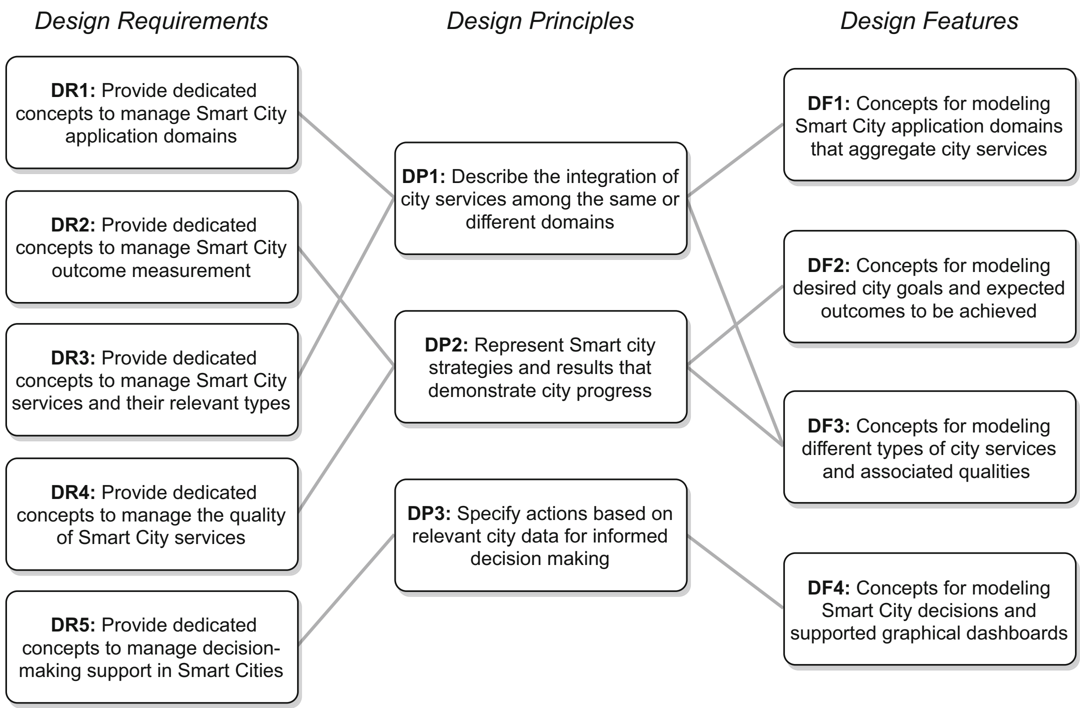


Fig. 1 Mapping design requirements to design principles and design features

and service composers to compare alternative services (Jureta et al. 2009). The quality of city services is closely associated with customer satisfaction and the overall well-being of citizens. Since service quality is a multi-dimensional construct, schematic representation of quality dimensions of city services (e.g., reliability, customer satisfaction, etc.) is essential to represent the quality expectations (Sá et al. 2016; Schulte et al. 2017). It is also necessary to express the quality attributes or non-functional properties of application services such as availability, security, privacy, etc. (Weber and Podnar Žarko 2019). The definition and representation of these qualities during service design support the development and improvement of both city services and their correspondent application services.

DR5: *It is required to provide dedicated concepts to manage decision-making support in Smart Cities.*

Smart Cities involve multiple stakeholders with different responsibilities who make decisions at different levels to achieve city goals (Carli et al. 2016). Modeling decisions improve the visibility and focus of decisions based on required information (Janssens et al. 2016). Dashboards support strategic, tactical, and operational decision-making (Sarikaya et al. 2018). Public authorities use data-driven dashboards that visualize the necessary information collected from diverse data sources (e.g., real-time APIs, social media, sensor networks, etc.) (Matheus et al. 2018). Dashboards are becoming an important instrument for governments to create transparency, achieve accountability, and stimulate citizen engagement (Harrison and Sayogo 2014). Citizens use dashboards to improve their everyday living and decisions based on real-time information about the weather, air pollution, public transport (Kitchin 2014).

4.2 Formulation of Design Principles and Features

This section presents the Design Principles (DP) and derived Design Features (DF) (see Fig. 1). These principles are conceptualized to address the defined design requirements. They are formulated in terms of materiality, action, and boundary conditions for the design of the intended artifact following the structure and approach suggested by Chandra et al. (2015) as follows.

DP1: *Provide the modeling language with the capability to express Smart City application domains in order for users to describe the integration of city services among the same or different domains.*

Rationale: The modeling language should be able to represent and visualize the Smart City application domains (e.g., education, health, mobility, living, environment) to which city services (e.g., air-quality service, car-sharing service, health-service) belong. It should allow relevant for users (e.g., city authorities, enterprise architects, and service providers) to design coherent models that enable the integration of cross-domain city services from an early stage of design.

DP2: *Provide the modeling language with the capability to express Smart City strategies and outcomes in order for users to represent the expected results that demonstrate city progress.*

Rationale: The modeling language should be able to describe common outcomes for multiple stakeholders (e.g., city authorities, citizens, and service providers). It should be allow users to model and visualize a feasible, time-targeted, and measurable target that a Smart City seeks to reach in order to achieve its city goals. Besides, it should be able to represent outcome measurement in terms of both outcomes citizen-centric outcomes as well as other quality outcomes (e.g., city service qualities).

DP3: *Provide the modeling language with the capability to express Smart City decisions and related concepts in order for users to specify actions based on relevant city data for informed decisions.*

Rationale: The modeling language should allow users to model and visualize the roles or responsibilities that stakeholders play in the city and the decisions in which they participate. It should be able to describe the decisions made at different levels (e.g., strategic and operational) when designing or managing a Smart City. Moreover, it should be able to represent the graphic dashboards that visualize important city information to support decision-making.

In the following, design principles are assigned to specific design features (DF) (see Fig. 1). Design features are specific ways to implement a design principle in an actual artifact that close the last step of conceptualization (Meth et al. 2015). Table 1 compiles the design requirements (DR), design rationale, and proposed concepts according to each derived feature (DF). The design features are implemented in an expository instantiation in the next section.

DF1: *Represent concepts for modeling Smart City application domains that aggregate related city services.*

This paper proposes to model the *Domain* concept as well as its relationships with other concepts in order to address the DP1. In this way, the modeling language can represent Smart City application domains and their relationships with city services, goals, indicators and other concepts. This is particularly relevant in integrating city services from multiple-domains to respond to the goals and objectives of diverse stakeholders.

DF2: *Represent concepts for modeling desired city goals and expected results to be achieved.*

This study proposes to model the following concepts to address the DP2. The *Goal* concept to explicitly represent expected results to be reached. The *Objective* concept to decompose city goals in more specific milestones to achieve the overall city goals. This definition is inspired by the Business Motivation Model (BMM) where goals and objectives are used to support the vision or aspirations (Object Management Group 2015). The *Indicator* concept to link city objectives to city indicators. The *Quality of Life Dimension* concept since the quality of life is a key element for the development of Smart Cities.

DF3: *Represent concepts for modeling different types of city services and associated qualities.*

This study proposes the following concepts to address the DP1 and DP2. The *City Service* concept to represent the main type of services in the context of Smart Cities. The *Application Service* concept to realise city services by software applications. The *API* concept is defined because of its relevance to Smart Cities as several services are implemented via application programming interfaces. The *Quality of City Service* and *Quality of Application Service* concepts are defined since they are elemental to assess services.

DF4: *Represent concepts for modeling Smart City decisions and supported graphic dashboards.*

This paper proposes to model the following concepts to address the DP3. The *City Stakeholder* to represent all different stakeholders (e.g., city authorities) who are responsible for the decision-making process in cities and municipalities. The *Decision* concept to describe decision-making activities for the strategy definition, urban planning, and city operation. The *Dashboard* concept to represent graphic dashboards that visualize and analyze important information on cities, citizens, institutions, and their interactions. This information serves diverse decision-making processes that affect the quality of life for the citizens (Rojas et al. 2020).

5 The ArchiMate Extension

In this section, design features are implemented in an expository instantiation by extending the ArchiMate metamodel. The Archi modeling tool (ArchiMate 3.0.1) was used to develop the extension by means of a modeling method engineering (Visic et al. 2015). This instantiation makes the proposed concepts actionable by providing their descriptions and graphical notations, see Table 2. The source code of the ArchiMate extension is available on a public GitHub repository for the research community and practitioners[1]. The concepts are structured within the service and information layers and inherit the relationships from existing ArchiMate concepts, see Fig. 2. The concepts have the initials SC (Smart Cities) located in the left

[1] ArchiSmartCity - https://github.com/vivikaing/ArchiSmartCity.

Table 1 Design requirements (DR), design rationale and related design features

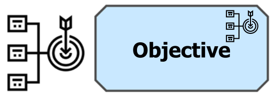
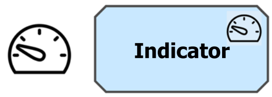
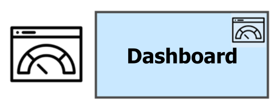
DR	Design rationale	Design features	Supporting source
DR1	Smart city application domains are essential to define how city services from multiple domains will be integrated. They can represent a particular domain (e.g., mobility) or sub-domain (e.g., pedestrian mobility) of Smart Cities. This specification can allow the interoperability of city services from their design phase	**DF1:** - Domain	Cabrera and Clarke (2019), Hefnawy et al. (2015), Ma et al. (2016), Michelucci et al. (2016), Neirotti et al. (2014)
DR2	Measuring the outcomes of city services and the impact on the quality of life for the citizens is a crucial task for Smart City managers and decision-makers. This specification can allow city managers to measure Smart city outcomes (e.g., citizen-centric outcomes as well as other quality outcomes) according to city goals and objectives	**DF2:** - Goal - Objective - Indicator - QoL Dimension	Al-Nasrawi et al. (2015), ISO37120 (2014), Loo and Tang (2019), Zdraveski et al. (2017)
DR3	Services are central to Smart Cities at different levels, including the city service and information systems levels. The distinction of these types of city services and their interfaces can allow the representation of the closest services to city authorities, service providers, information systems managers, and citizens	**DF3:** - City Service - Application Service - API	Bifulco et al. (2016), Bouguettaya et al. (2017), Nesi et al. (2016), Oktaria et al. (2017), Pourzolfaghar and Helfert (2017), Purohit and Kumar (2019), Yeh (2017)
DR4	Meeting the quality expectations of city services and application services is important to provide efficient services to different stakeholders. The quality of application services can impact the quality of associated city services. This specification can allow city managers to control the quality of services that affect citizens	**DF3:** - Quality of City Service - Quality of Application Service	Jureta et al. (2009), Sá et al. (2016), Schulte et al. (2017), Weber and Podnar Žarko (2019)
DR5	Decision-making support based on city services information is fundamental for Smart City managers. This specification can allow Smart City authorities to identify decisions, decision-makers, required information, and graphical user interfaces	**DF4:** - City Stakeholder - Decision - Dashboard	Carli et al. (2016), Harrison and Sayogo (2014), Janssens et al. (2016), Kitchin (2014), Matheus et al. (2018), Sarikaya et al. (2018)

corner of the figure. Only the most important ArchiMate concepts and their relationships are represented in order to clearly presenting the metamodel extension.

The Service Layer presents the main ArchiMate concepts including the business concepts (yellow concepts), motivation concepts (purple concepts), and composite concepts (i.e., location and grouping). This layer is augmented with the following concepts: the *Domain* concept is a specialization of the Grouping concept. This enables the *Domain* concept to group other concepts that share one or more characteristics relevant to Smart Cities according to the design feature DF1. The motivation concepts of TOGAF are used to model the Smart City outcome measurement through the concepts: *Goal, Objective, and Indicator* in order to realize the design feature DF2. For this feature, the *Quality of Life Dimension* concept is implemented as a specialization of the *Business Object* concept. This concept is associated with the *Indicator* concept to measure citizen-centric outcomes as well as other quality outcomes over time (e.g., quality of city services). The *Business Service* concept is used to represent the *City Service* concept in accordance with the design feature DF3. The *Decision* concept is a specialization of the *Process* concept that represents a city decision in order to realize the design feature DF4.

The Information Layer presents the main ArchiMate concepts of the application layer (blue concepts). This layer is augmented with the following concepts: the *API* concept is a specialization of the *Application Interface* concept in accordance with the design feature DF3. This concept can be assigned to an *Application Service* to expose application services to end-users or other systems. The *Quality of Application Service* concept is implemented as a specialization of the *Data Entity* concept to describe the performance characteristics of application services according to DF3. The *Dashboard* concept is a specialization of the *Application interface* concept to realize the design feature DF4.

Table 2 Description of the Smart City concepts and their graphical notation

Concept	Graphical notation	Description
Domain		A key field of urban development in Smart Cities such as smart economy, mobility, environment, etc.
Objective		A milestone for a Smart City used to demonstrate progress towards a city goal.
Indicator		A quantitative, qualitative, or descriptive measure required to demonstrate the outcomes in terms of city services and quality of life.
Quality of Life Dimension		A dimension that represents qualitative aspects of individuals that are impacted by the services available in cities.
Quality of Application Service		A quality support or performance characteristics of an application service.
Application Programming Interface		A software service that allows communication between two software programs in a network.
Decision		An option or action based on the data collected to support the decision-making process.
Dashboard		An interactive application interface that provides city managers, businesses, and citizens with a view of the urban condition.

The Alignment of the Service and Information Layers is modeled by connecting them through two main kinds of relationships: *Serving relationships* and *Realization relationships*. The *Serving relationships* represent that a concept provides its functionality to another concept, for example, between a *Dashboard* concept and a *Decision* concept. The *Realization relationship* represents that a concept is fundamental for the creation, achievement, or operation of a more abstract concept. For example, an *Application Service* concept realizes a *City Service* concept. There can be an aggregation relationship between a *Domain* and information concepts to indicate the domain where they belong in order to realize the design feature DF1.

6 Case Study

In this section, a case study is presented to demonstrate the realistic use of the proposed concepts for modeling Smart Cities. For this purpose, firstly, we present a case study that concerns on a waste management service in Netanya municipality. Secondly, we used the extended metamodel to design architecture models specific to the case study by asking the primary stakeholders for feedback on the developed artifacts.

6.1 Case Study Description

Netanya is a city of about 250 thousand citizens covering a total area of 35,000 square kilometres, with 70,000 housing units and 1.2 million square meters built in industrial and business parks. Becoming a Smart City is a paramount aspect of the policy of Netanya, as part of the desired development. Netanya is required to progress in many areas, such as strategy, organizational culture, intraorganizational processes, information systems, technologies, and services, particularly digital services for its residents. Netanya has set a goal of being a resident-centric city, by analyzing the needs of the residents and investing in different platforms to improve their quality of life.

We explore a waste management service in Netanya due to the efficient management of waste has a significant impact on the environment and thus on the health of

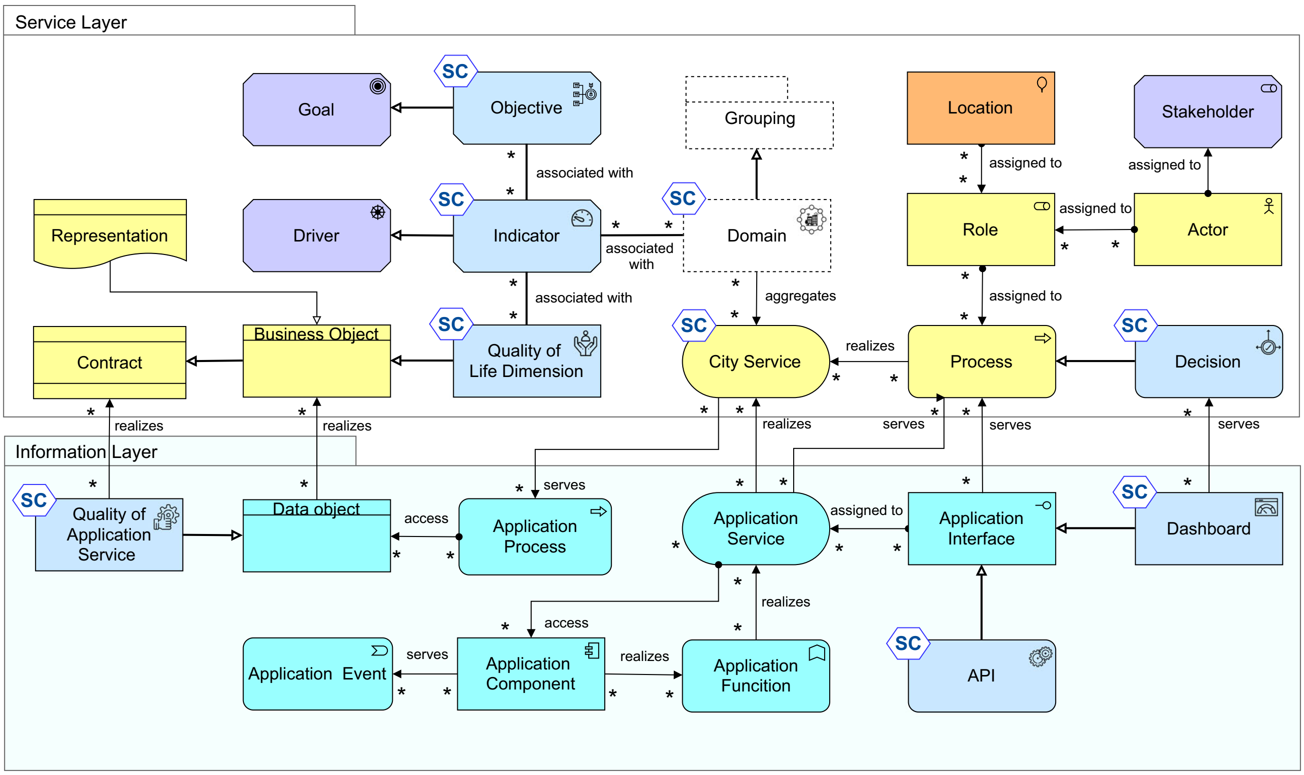


Fig. 2 Smart City metamodel extension

citizens (Pérez González and Díaz Díaz 2015). Waste management involves not only the collection of the waste in the field but also the recycling, transport, and disposal to the appropriate locations (Anagnostopoulos et al. 2017). Netanya serves 27 neighborhoods and collects 134,342.05 tons of solid waste produced per year in the city. On a daily basis, the municipality of Netanya uses 25 trucks with a capacity of 4 tons per truck. In accordance with the national waste management regulations, Netanya municipality recycles 17.61 percent of municipal waste produced in the city, including organic waste, paper, plastic and glass. The recycling target in the Strategic Plan 2030 of the Ministry of the Interior is 51 percent of waste recycled.

Netanya municipality tracks the resident feedback in real-time and over time to understand the needs of residents and the impact of Smart initiatives. A dashboard aggregates different data sources from external and internal channels such as social media and the city hotline. The system runs a sentiment analysis to determine if the data reflects positive, negative, or neutral feedback on several city services. Figure 3 presents a series of interactions on the waste management service that help Netanya city to visualize localized problem by neighborhood. Most of the interactions of residents are in the city center (e.g., neighborhoods 6,7), where there is a negative feedback related to the garbage collection (red color).

Netanya city managers plan the future state of the service by digitizing certain activities that affect garbage collection to solve this problem: (1) in the recycling of the garbage from the production source during the recycling activity, (2) in the dynamic adaptation of routes that affect the collection of waste during the collection activity. We model waste management as a city service on top of information systems in the city. We instantiate the extended metamodel by designing a solution for the waste management service.

6.2 Enterprise Architecture Models

This section provides two solution concept diagrams within the case study to illustrate the use of the extended metamodel. Solution concept diagrams illustrate concisely the major components of the baseline (as-is) and target architectures (to-be) (The Open Group 2018). Appendix B details the solution concept diagram of the baseline architecture and Fig. 4 depicts the target architecture using the ArchiMate extension. The target architecture represents the vision for the next 3 years in Netanya City. It is

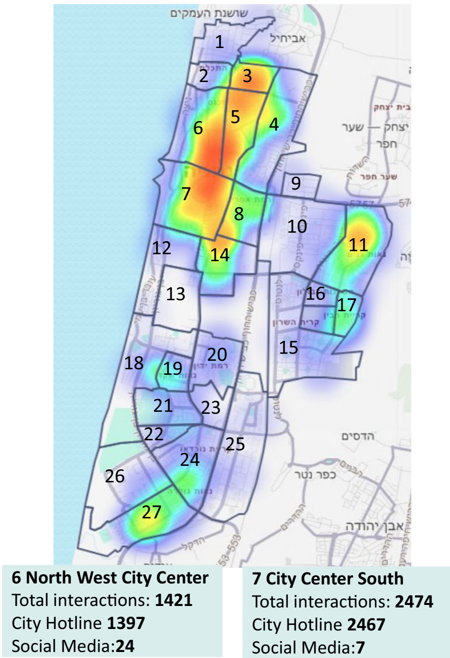


Fig. 3 Netanya citizens interactions per neighborhood on the waste management service

modeled within a layered architecture description as outlined below.

First, the ArchiMate extension allows to define the future Smart City strategies and plan accordingly. Hence, this extension helps to model and refine future high-level city goals into more concrete objectives. For example, the diagram depicts a high-level orientation of the solution to address a specific objective: “Recycle 51% of the solid waste according to the 2030 Strategic Plan of the Ministry of Commerce”. This objective is used to demonstrate progress towards both goals: “Increase recycling to reduce the environment impact of waste landfills” and “Make Netanya city and human settlements inclusive, safe, resilient and sustainable”.

Second, the ArchiMate extension helps to measure the quality of city services through city indicators, such as: “Percentage of the city’s solid waste that is recycled”. This indicator impacts the quality of life dimensions, including “Housing Conditions”, “Environmental Quality” and “Health” for the citizens living in areas of the city center. Besides, the indicator is associated with the “Livability” domain which aggregates the “Waste Management City Service”, enabling the link of city services that share common characteristics in Smart Cities.

Third, the ArchiMate extension helps to identify how current city services and decisions are realized by information systems. The future state of the waste management city service includes the use of Pneumatic Waste Collection (PWC) technologies in order to improve recycling in the city. Therefore, the “Head of Operations Administration” has to make the decision: “Choose a provider for PWC”, considering a “PWC Control System” that should be integrated into the existing “Routing System” for the garbage collection.

Finally, the ArchiMate extension helps to define how to automate city decisions using new technologies. For example, The future state of the waste management city service considers the dynamic adaptation of routes during the garbage collection activity. The solution incorporates a “Sensor BIN API” which provides the bins fill level information to the “Routing System”. Sensors located in waste bins can provide real-time data on their fill status, enabling automatic optimization and prioritization of waste collection routes. These qualities of application services such as “Security, “Confidentiality” “Availability”, and “Accuracy”, may, in turn, affect the quality of the waste management city service. For example, if the ”Routing System” is not available, it will impact the “Waste Management City Service” and in particular garbage collection, affecting the quality of life for the citizens. This specification is important for the formal tendering of service providers of sensors and their corresponding APIs.

7 Evaluation

For the evaluation, we follow Helfert et al. (2012) to assess the *utility* and *quality* of the proposed concepts for modeling Smart Cities. The evaluation includes the assessment within the case study and the validation of the concepts by experts in order to corroborate our proposal.

7.1 Evaluation within the Case Study

We evaluate the *utility* of our proposal as a form of assessing whether the artifact fits the purpose and meet the users subjective needs (e.g., relevance) within the case study. During the data collection, we asked the Smart City domain manager and waste management process owner on the importance of the design requirements to manage the city services and their information systems. All the requirements discussed during the semi-structure interviews were relevant to the stakeholders.

We also held a meeting to evaluate the resulting models for the waste management service solution created. First, we presented the models created, according to the collected data and the feedback of stakeholders during the solution design. Second, a semi-structured interview was conducted to ask the opinion of the Smart City domain manager on the relevance of the proposed concepts and their use in each model. The overall evaluation of the proposed concepts and

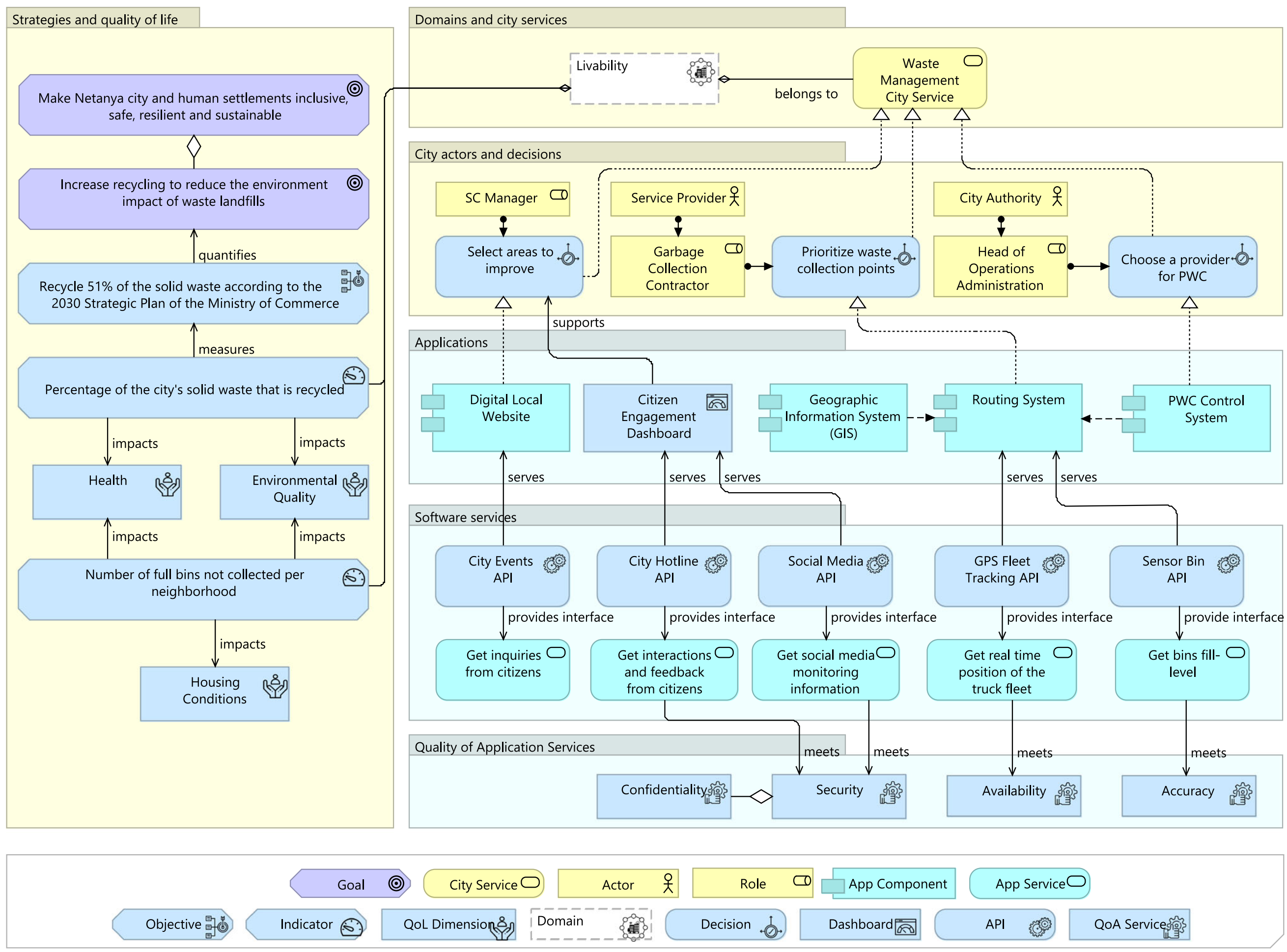


Fig. 4 Future state: Solution diagram for Netanya waste management city service modeled using the ArchiMate extension

solution was positive. The domain expert stated: "these concepts enable the management and oversight of a variety of systems and services". The domain expert also said: "the different models, for example, the service catalog grouped by domains, is interesting for people from the municipality to see the current work areas, associated problems and future development of services to serve the needs of residents". More details of the interview can be found in "Appendix C".

7.2 Evaluation by Smart City Domain Experts

A semi-quantitative survey is used to evaluate the proposed concepts and the ArchiMate extension, see "Appendix D". We requested the judgment of a group of Smart City domain experts to evaluate primarily the *quality* of our proposal. The participants involve the Smart City domain manager of Netanya municipality and five senior directors and managers of the Federation of Local Authorities in Israel. The roles of the participants within this Federation include the CEO, the Deputy CEO, the Director of Innovation, the Director of MuniExpo - Urban Innovation Fair, and the Director of Infrastructure and Urban Development. They were selected because of their expertise in the public sector and their work in the Smart Cities field that impact different aspects of daily life for all Israeli citizens (e.g., urban planning, education, transport, and more).

A meeting was held with the domain experts where they received a QR code to access a survey with seven modeled scenarios. Each scenario presents a description and questions related to the *quality* of the proposed concepts, including the *abstract syntax (concepts and relationships) and concrete syntax (graphical notation and descriptions)*. Table 3 presents the general feedback received from the domain experts that was positive; more details can be found in "Appendix C". They highlighted the high relevance of the problem addressed. Common concerns and suggestions (e.g., graphical notations) were used to improve our proposal.

Table 3 Detailed expert feedback

Topic	Transcription from the survey
Concepts	**A:** "The concepts you suggest indeed give an instrument to simplify the discussion regarding a rather complicated field and might be used to build a common language."
	B: "The concepts proposed represent a wide contribution to Smart Cities and it is connected to the reality to support the municipalities."
	C: "These concepts are useful for us as managers and decision-makers because this is what we do every day. The flow of the models helps to understand the city services and solutions."
	D: "The definition of the goals in Smart Cities is generic, for example in the model, the first goal is too general (It can be suitable for security as well as a building). So, the definition of the objective concept is good to specify more the goals."
	E: "I like the flow for describing the models and the graphical notations to present the concepts."
City Service	**F:** "It is important that you chose a waste management service because it is an example easy to understand and relevant for any city."

7.3 Internal and External Validity

Validity can be divided into internal and external validity. Internal validity concerns the causal relations investigated during the case study and factors influencing the design process (Rurua et al. 2019). In this study, these factors include our experience in modeling EA in the public sector and Smart Cities in collaboration with cities in Ireland and Israel as well as the multiple perspectives of stakeholders on the modeled scenarios. External validity refers to the extent to which the findings can be generalized (Rurua et al. 2019). Conducting a single case study can affect the generalizability of the concepts. Thus, it is important to conduct other case studies to ensure the generalization of the findings beyond the current city service and geographical scope.

8 Discussion

8.1 Theoretical and Practical Contributions

First, this research builds an understanding of the different concepts for modeling Smart Cities to provide a coherent EA description of this field. Understandable concepts for Smart Cities allow stakeholders to manage the complexity of and support continuous alignment while designing the digital transformation of public services (Helfert et al. 2018). Moreover, this study proposes an approach to extend ArchiMate for Smart Cities where domain-specific elements are required, thus expanding EA modeling capabilities into this field. For instance, we define the domain concept as an instantiation of the grouping concept and model its relations with city services, allowing the integration of services within the same or different domains since the early stage of design. Our observations suggest that this tool is valuable for practice as it enables Smart Cities managers and designers to use an EA modeling language close to the domain experts as a means for communication between them.

Second, this research provides design principles and features as abstract prescriptions for the design of modeling methods for Smart Cities. Unlike the existing research that considers the modeling approaches and methods in other fields, there is a lack of an EA modeling perspective in the Smart Cities domain. This research formulates the design principles as explicit prescriptions on how to address the conceptual modeling of city services and underlying information systems in Smart Cities contexts. The proposed design features can be traced back to the design requirements through the design principles. Together, they provide the conceptual understanding and relevance of the proposed ArchiMate extension.

Third, our case study demonstrates the application of the ArchiMate extension by designing a city service solution according to city goals and objectives where the technology is only the enabler of the solution. This is important to advance the concept of Smart Cities, as research has so far primarily focused on technical and engineering challenges with little attention to how to achieve desired outcomes (e.g., sustainability, economy, society, and governance) (Pérez González and Díaz Díaz 2015). In this paper, the definition of city goals and objectives is inspired by the Business Motivation Model (BMM) (Object Management Group 2015). According to the BMM, goals and objectives are used to support the vision (motivation) and courses of action and capabilities are strategies to achieve the vision. Although ArchiMate represents courses of action to define how capabilities will be used, the objective concept is not explicitly defined. This paper models the objective concept to demonstrate progress toward city goals. Objectives are linked to indicators to measure the real effectiveness of Smart Cities. The Indicator concept is used for both measuring the quality of city services and quality of life.

Fourth, in practice, it is very difficult to have an overall perspective on the architecture changes and provide city authorities and architects managing the changes with the information they need. City authorities have to manage many broad initiatives in different domains (e.g., mobility, environment, sustainability). We envisage that our proposal can assist cities in this challenge. For example, city managers can plan the integration of various city services, before developing individual solutions that create application silos. The proposed concepts can be used as a guideline for municipalities that address Smart City initiatives, allowing the consideration of various views and strategic aspects of city services. The ArchiMate extension can help city managers and enterprise architects to use a common language to design different solutions, resulting in coherent and integrated models to support decision-making that affects the quality of life for citizens.

Fifth, this paper identifies how current city services are realized by information systems (e.g., application services, APIs, dashboards) in Smart Cities. Many service providers offer APIS such as web services to automate city services and city managers have to deal with their qualities (e.g., availability, security) (Purohit and Kumar 2019; Bastidas et al. 2018). Such APIs collect and produce useful information to support decision-making, using graphic dashboards and other monitoring applications. Therefore, decisions, dashboards, and city stakeholders are defined as concepts for modeling Smart Cities and guide the decisions of city managers. Finally, although the ArchiMate extension is particular for Smart Cities, the proposed concepts may be used in other contexts with similar layered architectures (i.e., services and information layers). For instance, smart healthcare in the context of IoT may require to describe domains (e.g., monitoring, diagnosis, telecare, etc.) and associated services (e.g., patients remote monitoring). In this way, hospitals can implement their IoT-based services that interact across different domains aligned to their strategic plans to improve the quality of life for the patients.

8.2 Limitations

First, since our proposal tackles the conceptual modeling side, we do not connect the models to real data. Using our proposal as a foundation, cities, and municipalities could enrich their architecture models with real-time urban data (e.g., city indicators, citizens feedback from social media, and quality of life over time) and display the results in various dashboards. These dashboards can be shared with relevant stakeholders in the cities, including strategic decision-makers as well as operational stakeholders. For instance, a dashboard can visualize when there is a problem of alignment due to the indicators of city services are not reaching the established target levels using real data. Therefore, future research should continue investigating how to close the gap between strategic and operational planning tools in order to make decisions based on all relevant city data using integrative planning solutions.

Second, we use the feedback from residents to understand their needs and improve the waste management city service in Netanya. However, we did not involve them in the co-creation and planning process of the city service solution. Thus, future research should engage citizens and provide means for them to participate in these activities. Finally, this research explores the modeling of Smart Cities and validates the findings in a single case study. A single case study provides empirical richness and a holistic and real-world view of the problem under study. However, the generalizability of a larger sample of cases points towards a potential limitation of our work, since the case study is restricted to Netanya city and its waste management city service. Hence, future research should conduct other case studies to ensure the generalization of the findings beyond the current city service and geographical scope.

9 Conclusion

The public sector is enabled with the advance in IT solutions that make the provision of city services more efficient, thus improving the quality of life for the citizens (Pérez González and Díaz Díaz 2015). This digitalization leads to complex IT systems that need to be integrated and managed in a structured manner to address multiple city goals. A relatively small number of existing EAs for Smart Cities describe different components and layers to support their implementation. However, there is no specific focus on the concepts for modeling city services and the underlying information systems aligned with Smart City strategies.

In this paper, we provide design principles and features as abstract prescriptions for the design of modeling methods and tools for Smart Cities. We derive the concepts for modeling Smart Cities in ArchiMate based on these prescriptions. We focus specifically on the concepts to support the management of city services (e.g., domains, city services, quality of life) and their information systems (e.g., dashboard, API, quality of application services) aligned with city goals and objectives. For example, the definition of the domain concept and its relationships with city services allow the interoperability of city services from their design phase. These concepts were validated by the Smart City domain experts of Netanya municipality and the

Federation of Local Authorities in Israel. The findings suggest that these concepts are essential to design desired services, achieve city goals, and meet the needs of different stakeholders. This is important to advance the concept of Smart Cities, as research has so far primarily focused on technical challenges.

Finally, the proposed concepts and the different models created were understood by domain experts and were used to communicate with them during the case study and evaluation phase. Considering the trend towards the digital transformation of the public sector and Smart cities, as part of the future work, we aim also to continue investigating the strategic alignment in these contexts. This can help cities and municipalities to design and offer desired services.

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References

Ahlemann F, Stettiner E, Messerschmidt M, Legner C (2012) Strategic enterprise architecture management: challenges, best practices, and future developments. Springer, Heidelberg

Ahlers D, Wienhofen LW, Petersen SA, Anvaari M (2019) A smart city ecosystem enabling open innovation. In: International conference on innovations for community services. Springer, Heidelberg, pp 109–122

Al-Nasrawi S, Adams C, El-Zaart A (2015) A conceptual multidimensional model for assessing smart sustainable cities. JISTEM J Inf Syst Technol Manag 12(3):541–558

Anagnostopoulos T, Zaslavsky A, Kolomvatsos K, Medvedev A, Amirian P, Morley J, Hadjieftymiades S (2017) Challenges and opportunities of waste management in iot-enabled smart cities: a survey. IEEE Trans Sustain Comput 2(3):275–289

Anthony Jnr B (2021) Managing digital transformation of smart cities through enterprise architecture: a review and research agenda. Enterp Inf Syst 15(3):299–331

Anthopoulos L, Fitsilis P (2014) Exploring architectural and organizational features in smart cities. In: International conference on advanced communication technology (ICACT), 2014 16th, IEEE, pp 190–195

Baskerville R, Pries-Heje J (2010) Explanatory design theory. Bus Inf Syst Eng 2(5):271–282

Bastidas V, Bezbradica M, Helfert M (2017) Cities as enterprises: a comparison of smart city frameworks based on enterprise architecture requirements. International conference on smart cities. Springer, Heidelberg, pp 20–28

Bastidas V, Helfert M, Bezbradica M (2018) A requirements framework for the design of smart city reference architectures. In: Proceedings of the 51st Hawaii international conference on system sciences, pp 2516–2523

Bifulco F, Tregua M, Amitrano CC, D'Auria A (2016) Ict and sustainability in smart cities management. Int J Publ Sect Manag 29(2):132–147

Bork D, Karagiannis D, Pittl B (2020) A survey of modeling language specification techniques. Inf Syst 87(101):425

Bouguettaya A, Singh M, Huhns M, Sheng QZ, Dong H, Yu Q, Neiat AG, Mistry S, Benatallah B, Medjahed B et al (2017) A service computing manifesto: the next 10 years. Commun ACM 60(4):64–72

Buckl S, Dierl T, Matthes F, Schweda CM (2010) Building blocks for enterprise architecture management solutions. In: Working conference on practice-driven research on enterprise transformation. Springer, Heidelberg, pp 17–46

Cabrera C, Clarke S (2019) A self-adaptive service discovery model for smart cities. IEEE Trans Serv Comput

Carli R, Dotoli M, Pellegrino R (2016) A hierarchical decision-making strategy for the energy management of smart cities. IEEE Transact Autom Sci Eng 14(2):505–523

Chandra L, Seidel S, Gregor S (2015) Prescriptive knowledge in is research: Conceptualizing design principles in terms of materiality, action, and boundary conditions. In: 2015 48th Hawaii international conference on system sciences, IEEE, pp 4039–4048

Cox A, Parslow P, De Lathouwer B, Klien E, Kempen B, Lonien J (2016) Espresso project d4.2 - definition of smart city reference architecture, systemic standardisation approach to empower smart cities and communities. http://espresso-project.eu/, Accessed 18 Sept 2019

Esmaeilian B, Wang B, Lewis K, Duarte F, Ratti C, Behdad S (2018) The future of waste management in smart and sustainable cities: a review and concept paper. Waste Manag 81:177–195

Harrison TM, Sayogo DS (2014) Transparency, participation, and accountability practices in open government: a comparative study. Govern Inf Q 31(4):513–525

Hefnawy A, Bouras A, Cherifi C (2015) Lifecycle based modeling of smart city ecosystem. In: The 14th international conference on information and knowledge engineering

Helfert M, Donnellan B, Ostrowski L (2012) The case for design science utility and quality-evaluation of design science artifact within the sustainable ict capability maturity framework. Syst Signs Actions: Int J Inf Technol Action Commun Workpract 6(1):46–66

Helfert M, Bastidas V, Pourzolfaghar Z (2018) Digital and smart services–the application of enterprise architecture. In: International conference on digital transformation and global society. Springer, Heidelberg, pp 277–288

Horkoff J, Jeusfeld MA, Ralyté J, Karagiannis D (2018) Enterprise modeling for business agility. Bus Inf Syst Eng 60(1):1–2

ISO37120 (2014) Iso 37120:2014 - sustainable development of communities–indicators for city services and quality of life. In: International standards ISO37120, first edition, International Organization for Standardization

Janssens L, Bazhenova E, De Smedt J, Vanthienen J, Denecker M (2016) Consistent integration of decision (dmn) and process (bpmn) models. In: Proceedings of the CAiSE'16 forum, at the 28th international conference on advanced information systems engineering (CAiSE 2016), CEUR-WS. org, vol 1612, pp 121–128

Jureta IJ, Herssens C, Faulkner S (2009) A comprehensive quality model for service-oriented systems. Softw Qual J 17(1):65–98
Kakarontzas G, Anthopoulos L, Chatzakou D, Vakali A (2014) A conceptual enterprise architecture framework for smart cities: A survey based approach. In: 2014 11th international conference on e-business (ice-b), IEEE, pp 47–54
Kitchin R (2014) The real-time city? big data and smart urbanism. Geo J 79(1):1–14
Lankhorst MM (2004) Enterprise architecture modelling - the issue of integration. Adv Eng Inform 18(4):205–216
Lara P, Sánchez M, Villalobos J (2019) Ot modeling: The enterprise beyond it. Bus Inf Syst Eng 61(4):399–411
Lnenicka M, Machova R, Komarkova J, Pasler M (2017) Government enterprise architecture for big and open linked data analytics in a smart city ecosystem. In: International conference on smart education and smart e-learning. Springer, Heidelberg, pp 475–485
Loo BP, Tang WS (2019) "mapping" smart cities. J Urban Technol 26(2):129–146
Ma M, Preum SM, Tarneberg W, Ahmed M, Ruiters M, Stankovic J (2016) Detection of runtime conflicts among services in smart cities. In: 2016 IEEE international conference on smart computing (smartcomp), IEEE, pp 1–10
Mamkaitis A, Bezbradica M, Helfert M (2016) Urban enterprise: a review of smart city frameworks from an enterprise architecture perspective. In: 2016 IEEE international smart cities conference (ISC2), IEEE, pp 1–5
Matheus R, Janssen M, Maheshwari D (2018) Data science empowering the public: Data-driven dashboards for transparent and accountable decision-making in smart cities. Govern Inf Q
McGinley T, Nakata K (2015) A community architecture framework for smart cities. Citizen's right to the digital city. Springer, Heidelberg, pp 231–252
Meth H, Mueller B, Maedche A (2015) Designing a requirement mining system. J Assoc Inf Syst 16(9):2
Michelucci FV, De Marco A, Tanda A (2016) Defining the role of the smart-city manager: an analysis of responsibilities and skills. J Urban Technol 23(3):23–42
Moody D (2009) The "physics" of notations: toward a scientific basis for constructing visual notations in software engineering. IEEE Transact Softw Eng 35(6):756–779
Neirotti P, De Marco A, Cagliano AC, Mangano G, Scorrano F (2014) Current trends in smart city initiatives: some stylised facts. Cities 38:25–36
Nesi P, Badii C, Bellini P, Cenni D, Martelli G, Paolucci M (2016) Km4city smart city api: an integrated support for mobility services. In: 2016 IEEE international conference on smart computing (smartcomp), IEEE, pp 1–8
Object Management Group (2015) Business motivation model, version 1.3. (2015)
Oktaria D, Kurniawan NB, et al. (2017) Smart city services: A systematic literature review. In: 2017 international conference on information technology systems and innovation (ICITSI), IEEE, pp 206–213
Peffers K, Tuunanen T, Rothenberger MA, Chatterjee S (2007) A design science research methodology for information systems research. J Manag Inf Syst 24(3):45–77
Pérez González D, Díaz Díaz R (2015) Public services povided with ict in the smart city environment: The case of spanish cities. J Univ Comput Sci 21(2):248–267
Petersen SA, Pourzolfaghar Z, Alloush I, Ahlers D, Krogstie J, Helfert M (2019) Value-added services, virtual enterprises and data spaces inspired enterprise architecture for smart cities. In: Working conference on virtual enterprises, pp 393–402
Pfeiffer D (2007) Constructing comparable conceptual models with domain specific languages. European conference on information systems ECIS
Pourzolfaghar Z, Helfert M (2017) Taxonomy of smart elements for designing effective services. In: Twenty-third americas conference on information systems (AMCIS), Boston, pp 1–10
Pourzolfaghar Z, Bastidas V, Helfert M (2019) Standardisation of enterprise architecture development for smart cities. J Knowl Econ pp 1–22
Purohit L, Kumar S (2019) Web services in the internet of things and smart cities: a case study on classification techniques. IEEE Consum Electron Mag 8(2):39–43
Rojas E, Bastidas V, Cabrera C (2020) Cities-board: a framework to automate the development of smart cities dashboards. IEEE Internet Things J pp 1–9
Rurua N, Eshuis R, Razavian M (2019) Representing variability in enterprise architecture. Bus Inf Syst Eng 61(2):215–227
Sá F, Rocha Á, Cota MP (2016) Potential dimensions for a local e-government services quality model. Telemat Inform 33(2):270–276
Sarikaya A, Correll M, Bartram L, Tory M, Fisher D (2018) What do we talk about when we talk about dashboards? IEEE Transact Visual Comput Graph 25(1):682–692
Schleicher JM, Vögler M, Dustdar S, Inzinger C (2016) Application architecture for the internet of cities: Blueprints for future smart city applications. IEEE Internet Comput 20(6):68–75
Schulte NA, Gellenbeck K, Nelles M (2017) Operationalisation of service quality in household waste collection. Waste Manag 62:12–23
Shanks G, Gloet M, Someh IA, Frampton K, Tamm T (2018) Achieving benefits with enterprise architecture. J Strateg Inf Syst 27(2):139–156
Silva N, Sousa P, da Silva MM (2021) Maintenance of enterprise architecture models. Bus Inf Syst Eng 63(2):157–180
Singh P, Lynch F, Helfert M (2021) Role of citizens in the development of smart cities: Benefit of citizen's feedback for improving quality of service. In: Smartgreens, pp 35–44
The Open Group (2017) Archimate® 3.0.1 specification. http://pubs.opengroup.org/architecture/archimate3-doc/, Accessed 18 Sept 2019
The Open Group (2018) Togaf® standard version 9.2
Visic N, Fill HG, Buchmann RA, Karagiannis D (2015) A domain-specific language for modeling method definition: From requirements to grammar. In: 2015 IEEE 9th international conference on research challenges in information science (RCIS), IEEE, pp 286–297
Walls JG, Widmeyer GR, El Sawy OA (1992) Building an information system design theory for vigilant eis. Inf Syst Res 3(1):36–59
Weber M, Podnar Žarko I (2019) A regulatory view on smart city services. Sensors 19(2):415
Webster J, Watson RT (2002) Analyzing the past to prepare for the future: Writing a literature review. MIS Q pp xiii–xxiii
Yeh H (2017) The effects of successful ict-based smart city services: From citizens' perspectives. Govern Inf Q 34(3):556–565
Ylinen M, Pekkola S (2019) A process model for public sector it management to answer the needs of digital transformation. In: Proceedings of the 52nd Hawaii international conference on system sciences
Zachman JA (1987) A framework for information systems architecture. IBM Syst J 26(3):276–292
Zdraveski V, Mishev K, Trajanov D, Kocarev L (2017) Iso-standardized smart city platform architecture and dashboard. IEEE Pervasive Comput 16(2):35–43
Zhuhadar L, Thrasher E, Marklin S, de Pablos PO (2017) The next wave of innovation - review of smart cities intelligent operation systems. Comput Hum Behav 66:273–281