A new enterprise architecture-based approach for smart city value co-creation

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ABSTRACT

In an era marked by vertiginous technological advancements and urban complexities, digital transformation has emerged to enable cities to offer smart services. This transformation optimizes interaction and collaboration between smart city actors, instead of working in isolated silos. There is a real need for a federative approach that can be aligned with urban vision and goals to support smart city implementation. In this context, enterprise architecture (EA) is emerging as a pivotal force reshaping smart city and supporting its development and transformation. However, the successful implementation of smart city depends also on the collaborative effort to co-create value among city's stakeholders. The present study develops a new approach based on enterprise architecture within the smart city ecosystem. Through methodical delineation our approach seeks to enhance value co-creation, improve smarter service design, and support community engagement.

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1. INTRODUCTION

Today, several fields are exposed to change due to the rapid growth and diversity of digital technologies. This change is called digital transformation. The latter is defined as the incorporation of digital technology into all fields and activities of an organization, which, in harmony, leads to infrastructural changes to deliver added value to its customers [1], [2].

The concept of a smart city is rapidly progressing. A smart city is a social structure that provides business, society, and technology [3]. An enterprise architecture (EA) refers to the fundamental structure and connections of elements of a system, the environment, and the guiding principles that govern system design and evolution [3], [4]. The advantages of adopting enterprise architecture are important in the enhanced stability of an organization in an environment of constant change.

Implementing smart cities involves more than just addressing technological challenges. It requires articulating smart projects for community initiatives to achieve desirable outcomes. Smart city adopts smart technologies and solutions to serve the community, enhance the services offered to citizens, particularly in sectors like health, education, electricity, transportation, communications, and others [5]. In response to the challenges posed by urbanization, the smart city transformation is increasingly becoming a central goal for numerous modern cities [6]. There is a myriad of smart city research works, including studies on the conceptualization of EA for smart city. An EA for smart cities should support common and complementary concerns of urban communities with the aim of producing the right and best services for its actors. As cities undergo transformation into digitally enhanced landscapes, the absence of a cohesive transformation model poses significant challenges [6].

Based on existing research, an EA for the smart city should address stakeholders' concerns to effectively improve city services. To this end, we present the EA-based value co-creation approach, which aims at federating the design of smart services. Our study presents the main components and concepts essential to generate collaborative value creation. Based on EA principles, the proposed solution introduces sequential methodology aiming to optimize smart services for better alignment of smart city initiatives with community needs. The evaluation demonstrates improved smart service efficiency and stakeholder engagement. Thus, the study innovatively integrates the principles of value co-creation, offering a new way of designing and implementing smart city solutions.

The paper is organized as follows: we introduce the study by a theoretical foundations section to present the background of the study. After, we present the research methodology adopted for our paper. We then present a comparative assessment of existing EA for smart cities. Following this, we introduce the importance of considering architectural requirements, service design, and value co-creation to overcome the smart city limitations. Next, we develop our approach, outlining its different phases. We evaluate the effectiveness of the proposed approach via simulation technique applied to a smart parking use case to demonstrate its effectiveness. Finally, we argue that the presented approach could address the concerns of smart city stakeholders, resulting in an improvement in smart services and value co-creation.

2. THEORETICAL FOUNDATIONS

2.1. Smart city background

Smart cities have been considered as ecosystems, which are generally defined as communities of organizations interacting with their environment and are usually described as complex networks formed due to the interdependence of resources [7]. The prefix “smart” indicates that the target solution is enhanced in its efficiency and function using Information and Communication Technology [8]. Nevertheless, important considerations including the interaction and interferences of different factors with smart infrastructure need also to be deeply addressed in the era of research.

Smart city implementation is a complex process that requires the integration of various technologies, stakeholders, and solution domains. Technical [8]–[11], financial and legal [12], [13], social and cultural challenges [14]–[16] are among the most prominent factors that hinder smart city implementation. Addressing these challenges requires a collaborative and innovative approach that involves all actors to provide intelligent solutions. To be defined as smart, smart city should involve the technological, environmental, and social aspects [17], [18].

Smart communities aim to use technology to enhance citizen well-being and living standards by digitizing and modernizing traditional processes [19]. From a general comprehension, a smart community is an emerging model designed to use internet technology to enhance both work and life experiences. Establishing an efficient information system is crucial for smart community implementation, to gather and process information in an efficient way. The smart city seeks to create an advanced technology and information-rich community that provides a variety of services aimed at creating a livable and safe environment characterized by convenience and extensive services [20].

2.2. Service design for smart community

New forms of partnerships between public sector entities are emerging, providing better value than the collective efforts of individual parts [21]. A service ecosystem approach serves as a model that enhances understanding of value creation, thereby empowering businesses with greater insights [22]. Several studies distinguish between three main levels of an ecosystem: macro, meso, and micro [23]. Indeed, the smart city model, mainly centered on the collaboration among stakeholders engaged in service provision process, can be examined in the service dominant logic context that enhance the engagement of diverse actors, not just as consumers of these services but also as active contributors to value creation process through feedback and collaboration. Their contribution is crucial in generating value that exceeds the sum of individual parts.

Value co-creation involves interactive activities among multiple stakeholders, that could encompass organizations or entities within a studied ecosystem. The participants collaborate by combining assets to co-create value propositions within the social environment in which they operate [24]. The interactions among actors promote co-creation, accessibility, clarity, and risk-benefit are the fundamental for this process [25]. Various city members are encouraged in co-creating value, if they are guided by common objectives. This collaborative effort, then, becomes effective with the support of advanced technology [26]. This last, represents a model comparable to a service ecosystem in which people, technology, and institutions, are appropriately combined to generate value that is then redistributed to all those who, in different measures and way, participate in its determination [27]. Figure 1 represents co-creation as a linear process, when in fact it continually improves results as incremental process change and transformative innovation [28].

Figure 1. Co-creation process adapted from [28]

Through a complex interaction between alignment and integration, a co-creation process for modeling knowledge-intensive business services is developed that includes two essential sub-processes: alignment and integration [29]. The alignment process brings the high-level interests of stakeholders, perceived benefits, value propositions, organized resources, and articulated deliverables together in a complex way. Conversely, the integration process revolves around how stakeholders evaluate and process the results of engagement. Stakeholders meticulously assess the quality of the deliverables and outcomes of the collaborative process, with positive assessments leading to the incorporation of the outcomes as new organized resources. These integrated results are then evaluated according to the high-level interests of the actors, leading to a positive determination of the value of the engagement [29].

2.3. EA for smart city

EA framework (EAF) refers to a logical structure to arrange and classify complex information. The EAF is defined as a collection of practices and conventions to depict architectures of an organization within a particular domain [30]. EA are structured methodologies used to design and manage the information technology (IT) and infrastructure of an organization. They provide a set of best practices and guidelines arranging and aligning an organization's diverse IT components to achieve its business goals. Enterprise Architecture is becoming increasingly used by modern organizations to organize their capabilities in response to the complexity and dynamicity of their business environments [31]. The model of layered architecture was proposed to minimize difficulty and enhance the structure of organizational development and advancement. Some popular frameworks are the Zachman framework [32], The open group architecture framework (TOGAF) [33], federal enterprise architecture framework (FEAF) [34], and the Gartner EA framework [35].

Cities are growingly using technology to cultivate new possibilities that create novel origin of competitive advantage. Also, EA provides a blueprint from which the system can be deployed, it entails the essential structure of an organization and facilitates digital transformation by providing a global view [36]. EA is employed to facilitate alignment between the strategic sustainability objectives of the city and IT that supports smart services for citizens [37].

Cisco framework defines in study [38] a conceptual smart city framework that helps stakeholders to perform smart city initiatives. The framework comprises four layers considering the city´s goals in social, environmental, and economic aspects. This framework presents a holistic overview of city goals and their relationship with city indicators. The city content layer deals with the implementation of smart city solutions. Moreover, an EA model is developed to provide solutions for Cirebon. The findings suggest that the smart city EA, based on TOGAF, can be adopted as a reference model for smart [39]. A big data work is studying innovative solutions for cooperating businesses and is proposing an EA that enables businesses to use a common data space to create value-added services by removing technical and organizational barriers [40].

Through the internet of things (IoT) optic, research presents a framework for the implementation of smart cities as an urban information system, from the sensory level and networking support structure [41]. This framework proposes an IoT infrastructure from three different domains: network-centric IoT for communication, cloud-centric IoT for management, and data-centric IoT for computation. This framework encompasses networking modules and their integration with the communication stack [41].

A community architecture framework for smart cities is presented to address the intricacy associated with managing multiple stakeholders, their interrelationships, and the conflict-of-interest resolution [42]. This framework is used to develop a tool to support developers, planners, and communities to engage in city planning by suggesting innovative ideas in their areas of interest. The research work is based on the Zachman framework. The concept of an Urban Enterprise is introduced in [43] which enables to view a smart city from the enterprise perspective. Urban enterprise is composed of multiple components that can be examined and evaluated separately.

According to the study presented in [44], an EAF for smart cities should consider specific concerns of the stakeholders and their world's issues with the aim of improving the quality of life for citizens. The framework introduces a structured approach that can manage smart cities. This framework focuses on establishing contextual requirements and definitions for smart services. Also, a cloud based general architecture for smart cities is presented in [45], facilitating access to real-time data collected via IoT for service providers, city managers, and residents. This ensures the delivery of necessary services and ameliorates quality of urban standards of living for residents. A research work study, conducted by [46], proposes an EAF for cities. The novel elements of this framework are DataxChange, the value-added services and virtual enterprise layers. This work carried out as part of the EU H2020 smart city project +CityxChange [47]. The objective outlined in this EAF is to help the city in their initiatives to enhance system and data alignment in offering smart services. This project is focusing on developing value-added solutions that can be replicated in other EU cities and exploitation in commercial markets beyond its duration [46].

The implementation of a smart community integrated service platform aims to leverage smart devices and software tools to implement an information platform for sharing useful data, integrating services, resource optimization, and to achieve smart management and innovation for communities [48]. In this work, the proposed approach presents a theoretical foundation for the implementation of the smart community. The proposed framework and its application system for the intelligent community integrated service platform offer a robust theoretical foundation for constructing smart communities. The study conducts a detailed analysis and design of the underlying infrastructure, supporting platform, and basic database of the platform [48].

Industrial data space (IDS), defined in [49], is a virtual data space leveraging existing standards and technologies, as well as accepted governance models for the data economy. This facilitates secure and standardized exchange and easy linkage of data within a trusted business ecosystem. As a result, it thereby provides a basis for smart service scenarios and innovative cross-company business processes, while at the same time making sure data sovereignty is guaranteed for the participating data owners [49]. The study [50] examines the data management needs of smart cities and suggests a framework for data governance to support decision-making, improve operational performance, establish data quality, and comply with regulatory compliance.

It is feasible to preserve the goals and perspectives of stakeholders, according to the community architecture framework presented in [51], which can enable them to find common ground without having to enforce standardized options for them to consider [51]. This contrasts with traditional EA frameworks which seek to represent the structured goals and perspective of a single organization. The opening of avenues for innovation in the design of smart cities is crucial because it would otherwise be daunting.

The study conducted in [52] aims to adopt EA for digital transformation of the city. The main goal of this research study is to present a framework to support interoperability and infrastructural flexibility within cities to address changes in business requirements. The presented framework helps to advance the city's digitalization goal by achieving a coherence and improving interoperability of human and technical infrastructure deployed in smart city [52]. Firdausy *et al.* [53] address this issue by reconciling data sovereignty and enterprise interoperability requirements within a reference EA. It seeks to help companies create instantiations or specializations of organizational and software components to meet specific business needs.

Otto *et al.* [49] presented an EAF to help companies determine the deployment of organizational and software components before entering an IDS ecosystem. The framework is designed to simplify the integration process by providing a structured approach. In addition, it improves the accessibility of the guidelines described in the IDS reference architecture model, making it easy for companies wishing to join IDS ecosystems to understand and follow the necessary steps.

Given the complex context of smart cities, the study presented in [54] discusses the opportunity of using community enterprise architecture to deal with the limitations of existing EA frameworks. Another study is developed to structure the relationship between citizens' feedback and continuous service improvement to meet the need of citizens [55]. It proposes a process model based on the guidelines of the TOGAF framework and the collaboration with practitioners that would assist local authorities in continuously providing improved services to the citizens [55].

3. RESEARCH METHOD

This research presents an EA based approach focused on value co-creation within smart cities, specifically aiming to address challenges faced during their implementation. The study is inspired by design science research methodology (DSRM) and has been adapted to meet the study's objectives and phases [56]. By refining the methodology accordingly, the research aims to provide solutions that can effectively contribute to the successful development of smart city.

The adoption of DSRM within our study is driven by several factors. Firstly, DSRM stands as a standard methodology in information system domain, renowned for augmenting the problem-solving capabilities of individuals and organizations amidst complex scenarios [56]. Secondly, DSRM furnishes a structured framework for crafting, evaluating, and refining artifacts, thereby ensuring the caliber and efficacy of resultant solutions. Lastly, DSRM facilitates the seamless integration of diverse research methodologies, facilitating a comprehensive evaluation and refinement trajectory. Peffers defined six phases for implementing the DSRM [56]. The first stage identifies the problem and explains the importance to solve it. The second stage is to determine the objectives of the proposed approach for solving the identified problem. The third stage is to design and develop an artifact that can be a construct, model, method, or instantiation. This necessitates a good understanding of the theoretical foundations that can be applicable for finding a solution. The fourth stage is to demonstrate the efficacy and efficiency of the artifact by using it to solve the problem. The fifth stage is to evaluate results by observing and measuring how effective the solution is in addressing the identified problem. The last stage is to communicate the developed solution to the scientific community. According to the DSRM phases, our research approach is described and modeled in Figure 2.

a. Problem identification and motivation: The existing literature on EA approaches for smart city rarely addresses value co-creation. Studies usually focus on technology and infrastructure, omitting the potential of interaction of city stakeholders. The result is a lack of approaches for active collaboration and community-centered service design.
b. Defining the objectives: The objective of our study focuses on supporting the implementation of smart cities through EA principles and value co-creation to enhance the design of smart services to respond efficiently to the community needs, with the ultimate goal of reinforcing engagement of city members.
c. Design and development: The proposed approach develops a step-by-step methodology to design smart services and generate co-created value according to community context. This proposed approach enables city stakeholders to design a federated smart city architecture toward smarter services, which is essential for aligning city services with community needs.
d. Demonstration: The use of the approach is initially demonstrated by applying it to one case study of smart parking. Further demonstration must take place by applying it to a new field. This is to be done yet.
e. Evaluation: The proposed approach is simulated by a simulation tool to evaluate the effectiveness of the developed approach.
f. Communication: The research findings will be shared with the scientific community through publications in conferences and reputable journals.

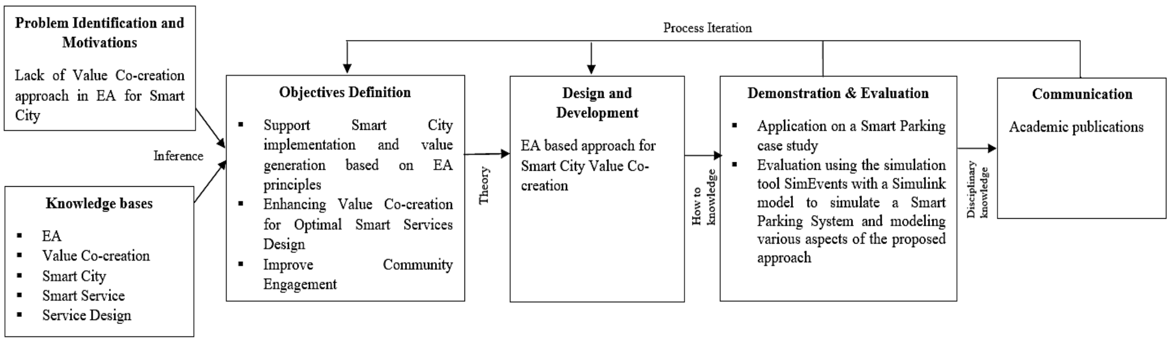

Figure 2. DSRM applied to our research work

4. PROPOSED APPROACH
4.1. Existing EA for smart city

This sub-section provides a high-level comparison study, analyzing the existing EA approaches in the era of smart cities. It compiles how much research works meet core prerequisites from an EA perspective. Each of the examined architectures has its own perspective on how to address complex issues. Although some of the architectures have considered stakeholders as one of the architectural components, none of the selected frameworks detail actor's interactions in smart city, and the incorporation of stakeholder's concerns in co-creating service and value. To conduct the comparison analysis of selected EA approaches, we establish the following criteria:

a. Architectural components: context, service, business, data, application, technology.
   – Context: Encompasses desires, needs, and requirements related to smart city concerns, along with associated key performance indicators (KPIs) that enhance the quality of life of smart city. It includes objectives, challenges, principles, and main requirements pertinent to smart city efforts. Additionally, the contextual layer addresses the interests of city members and communities.

   - Service: Includes the foundational elements and specifications including dictate the structure, functionality, and interoperability for the architecture of services within the smart city to meet business objectives.
   - Business: Captures all enterprises that contribute functions and processes to deliver digital services. It encompasses operational activities providing and delivering business services.
   - Data: Comprises real-time data from online applications, historical data, external data, and util knowledge bases.
   - Application: Include all systems involved in providing services for members of smart city.
   - Technology: Encompasses technologies implemented across smart cities, like cloud technologies, big data, and IoT.

b. Specific criteria: community interaction, service design, value co-creation.
   - Community interaction: Refers to the level of engagement and collaboration between the smart city actors. It focuses on involving individuals, businesses, and other stakeholders in decision-making processes, feedback mechanisms, and co-designing services.
   - Service design: Focus on planning and structuring of services. It explores the intricacies of how services are conceived, developed, and implemented to align with smart city vision.
   - Value co-creation: Encompasses the collaborative development and implementation of solutions by various stakeholders from variety of business in a complementary way to deliver smart services. Co-creation involves sharing ideas, knowledge, and resources to create innovative and value-added smart city solutions.

The evaluation of the listed criteria is conducted according to the scoring system described in Table 1. This scoring ensures that each criterion is assessed consistently. Thus, the comparative of EA for smart city gains clarity and provides a clearer interpretation.

Table 1. Comparative scoring

Evaluation	Description
++	Approach highly supports criteria
+	Approach partially supports criteria
-	Approach does not supports criteria

The examined EA approaches presented in Table 2 have several points in common: they highlight the alignment of EA with business objectives and requirements, the promotion of innovation and agility, and the importance of collaboration. Our literature review identifies various frameworks which deal with smart city goals. However, they do not provide a zoomed insight on their fundamental layers such as business, data, application, and technology. Rare frameworks describe how to co-create smart services toward digital transformation.

Although approaches yield valuable insights, it is important to recognize their inherent limitations, as shown in Table 2. The limitations in the existing EA frameworks designed for smart cities can be summarized as follows:

a. Lack of community aspects enhancement and prospects in actors' interactions. There is a limited consideration of community-centric elements such as communication, collaboration, engagement, and co-creation in the EAF for smart city. Also, there is a minimal exploration of interactions among smart city actors within existing frameworks, with a particular shortage in understanding the potential of value co-creation among actors in the ecosystem of smart city.
b. Scarcity of holistic architectural requirements coverage in smart city development. It has been noticed that the current smart EA frameworks do not address essential requirements and their relationships, including gaps in addressing contextual factors and service-related aspects.
c. Deficiency in the usage of service design paradigm for the conception of smart services. There is a scarce integration of the service design paradigm in the modelling of architecture for smart cities, indicating a lack of focus on community-centered design principles.
d. Lack of utilization of value co-creation in the development of smart city architectural approaches. Limited exploration of the interactions between smart city actors, with a particular dearth in understanding and harnessing the potential for value co-creation for designing an effective and valuable EA toward connected smart community.

Many architectural approaches present smart city like a set of isolated silos. Nevertheless, the focus on relationships between different actors of the evaluated frameworks is still absent or limited. Our proposed approach focuses on co-creating value and smart services. From our perspective, the smart city can be perceived as a set of interactive sub-communities. It requires more linked smart projects with respecting specific aspects of communities. Also, we can notice that rare frameworks involve a methodological roadmap to achieve federative and transformational goals.

With the vertiginous changes facing our world, smart cities, conceptualized as community enterprises, should position themselves to adeptly align and adjust their information systems efficiently by creating value to achieve its objectives and realize its vision. In the absence of a clear methodological blueprint, adaptations are often complex to implement, time-consuming and costly. The main challenge here relies on the ability of smart city to quickly transform toward smart community [54].

Based on the analysis of the existing studies and in response to the limitations identified in the studied approaches, we will refine the objectives of the proposed approach. Our approach aims to learn from the literature review, while proactively addressing the challenges and limitations identified, to precisely orient the objectives of the new proposed approach. Thus, the key objectives and components of the model are summarized in Table 3.

Table 2. Comparative of EA for smart city

Ref.	Approach	Context	Service	Business	Application	Data	Technology	Community interaction	Service design	Value co-creation
[56]	Enterprise architecture for the transformation of public services	-	+	+	-	-	-	++	-	-
[52]	Enterprise architecture for digitalization of smart cities	++	++	++	++	++	++	+	-	+
[53]	Reference enterprise architecture to enforce digital sovereignty in international data spaces	-	+	++	+	++	++	++	+	-
[42]	A community architecture framework for smart cities	-	-	-	+	+	++	++	-	+
[48]	Smart city community service integrated management	-	+	+	++	++	++	++	+	-
[49]	IDS-RAM framework	-	+	++	+	++	++	+	+	-
[46]	Enterprise architecture for +CityxChange	++	++	++	+	++	+	++	+	+
[44]	Designing EA for smart cities	++	++	+	+	+	+	-	++	-
[43]	Urban enterprise components from an enterprise architecture perspective	-	-	+	+	+	+	++	-	-
[45]	Smart city architecture for community level services through the internet of things	-	++	-	+	+	++	++	+	+
[40]	A big data analytics architecture for smart cities and smart companies	-	+	++	+	++	++	++	-	-
[39]	Smart city Cirebon framework	-	+	++	+	+	++	-	-	-

Table 3. The targeted approach purposes

Concerns	Why (Purpose)	What (Content)	How (Implementation)
EA for smart city value co-creation	Smart services	Smart city	Service design
	Value co-creation	Smart community	EA
	Aligning strategy, context, actor's interaction, business, data, application and technology	Providing a holistic blueprint for smart community	Smart community EA

4.2. Development approach for EA-based smart city value co-creation

The proposed approach provides a high-level overview of the relationship between strategy and relationship managements, community context, EA principles, service design and implementation, and the development of a smart cities toward an EA-based smart city value co-creation approach in Figure 2. In this work, we aim to develop an EA-based approach for co-creating value in smart city in Figure 3. The approach illustrates a model in which inputs from strategy and relationship management are used to guide the development of smart services that feed into the community context. Strategy management refers to the strategic planning and decision-making processes that determine the vision and objectives of the smart city. Relationship management involves managing the connections and interactions between the various actors in the smart city ecosystem, such as individuals, businesses, and public authorities, or external partners. The community context is created using the inputs provided to identify shared or mutually supportive needs and objectives among the various stakeholders involved in the smart city ecosystem.

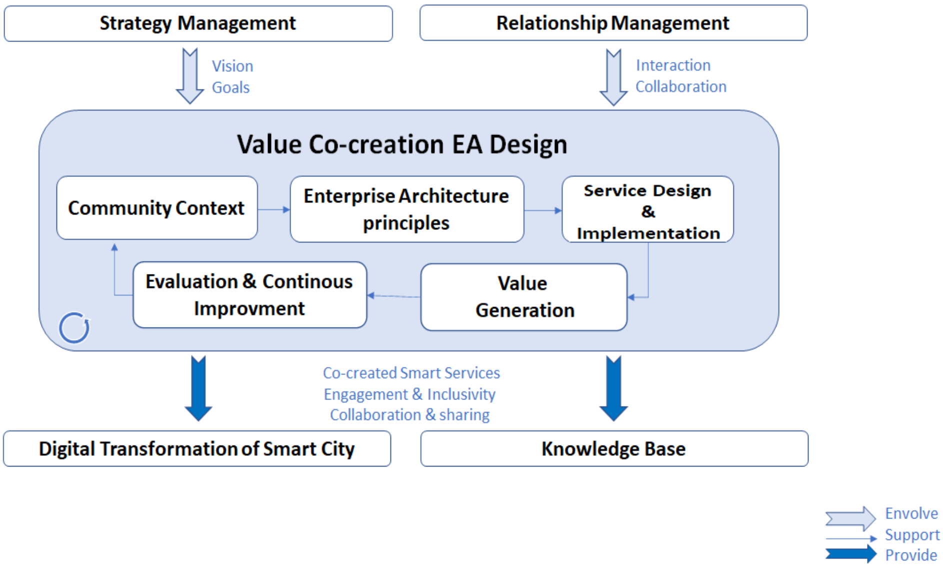

Figure 3. Overview of the proposed EA-based value co-creation model

According to the identified community context, the blueprint of smart city is structured as a reference to effectively adapt to community needs and goals. It is guiding the design and implementation of different shared or partially shared architectural components (business, data, application, and technology) to design and implement smart services that generate value. EA principles guide the customization of these principles to fit the specific context, which ensures the resulting city blueprint is fit to address the needs and dynamics of the communities. Service design is implemented to create value, enhancing co-creation among city actors. Interaction is crucial throughout the process, involving sharing and collaboration efforts between city stakeholders to continually adjust and improve smart services. This creates an iterative and continuous amelioration cycle focused on constant adaptation to maximize efficiency and smart community experience. The results of implementing smart services are then measured in terms of value generated and feedback gathered which feeds the knowledge base. Thus, the transformation is achieved by analyzing the community context and co-creation opportunities, developing a suitable architectural blueprint for smart cities toward, aimed at designing smart services that meet the community's needs.

We detail the common process phases inspired from co-creation process presented in [28] for developing our EA-based federative approach. The method is depicted graphically in Figure 4. We use the notation presented in [57], which is based on standard UML conventions, with some minor adaptations. The process shows the EA-based smart city value co-creation process, which begins with a meticulous understanding of community needs and goals, leading to the development of a resilient EA, design, and implementation of smart services toward co-creating value. Continuous improvement is the focus as it iterates in a cyclical return to the community context.

Phase 1 is community context identification. During the initial phase of the process, the focus is on locating the community context and identifying stakeholders who are relevant to the focus of interest [58]. Based on community engagement strategies and strategic city vision, the aim of this phase is to identify opportunities and challenges that may impact the operations of the smart city. With this comprehensive understanding, the smart city stockholder is better equipped to respond effectively to community expectations.

Phase 2 is analyzing requirements and value co-creation opportunities. The central objective is to analyze city requirements, determine relationships between stakeholders, and explore co-creation opportunities. In this phase, stakeholders are mapped according to their roles, including community actors and members. Developing their interests, constraints, expectations, and influence is central to perceive value co-creation in the smart community. In this stage, involving the community in value co-creation is an important aspect, with organized meetings and events designed to encourage collaboration, interactions, and a sense of shared ownership [59]. As the smart city executes its co-creation initiatives, it not only delivers value to the community but also solidifies its position as an inclusive participant within the community context. Thus, this phase analyses how city actors could interact together and understand relevant experiences and ideas for possible smart scenarios.

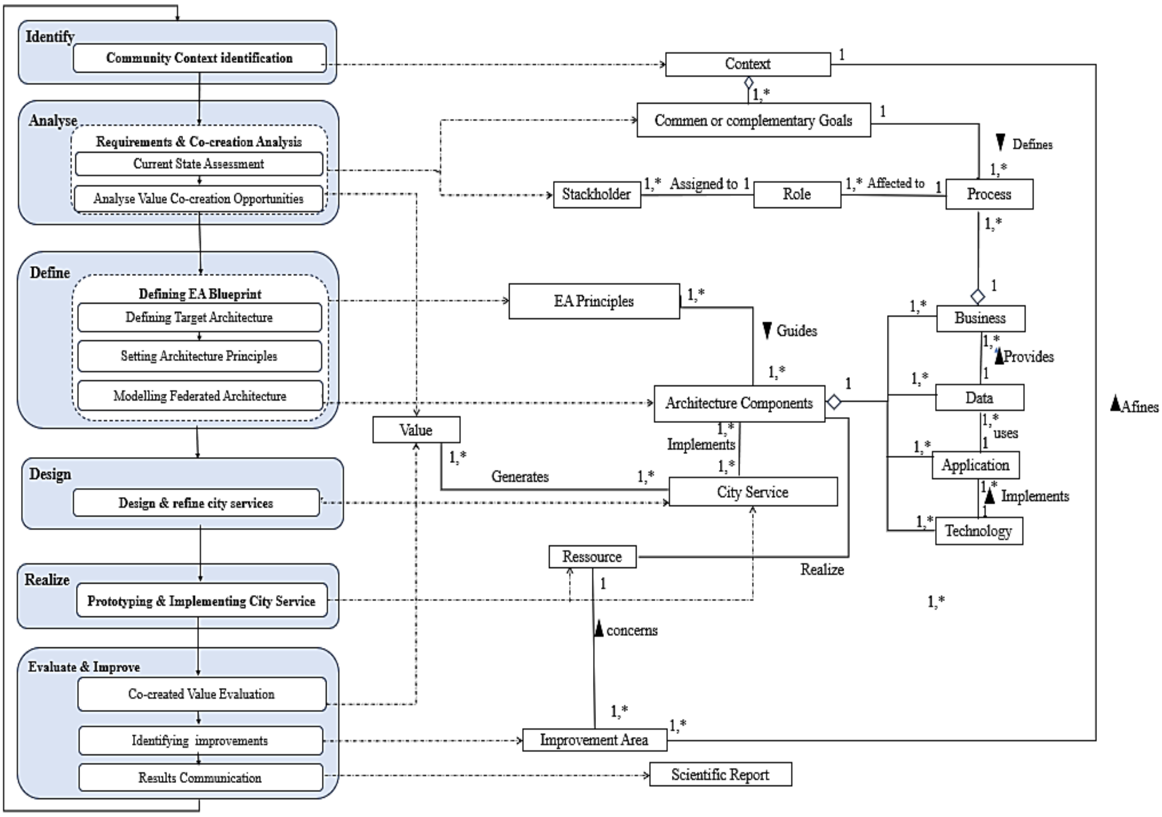

Figure 4. EA-based development approach for smart city value co-creation

Phase 3 is defining EA blueprint. In this stage, the smart city transitions from collaborative planning to structure definition, focusing on the development of a federative EA structure for the community context. Based on co-created strategies and stakeholder input, this phase is devoted to shaping guidelines that align with community needs and align with city goals. Through meticulous definition, architecture is defined to be federative and responsive to the dynamic era of community needs and goals. The design of city processes is a priority, ensuring that they align with the implemented architecture, and that they support the seamless execution of joint value co-creation initiatives.

The federated approach to EA is designed based on a community context and involves the collaboration and coordination of multiple smart city actors to create and manage a shared architecture that aligns with common or complementary goals and objectives toward value co-creation. In this stage, we prioritize value co-creation among stakeholders to ensure that smart city services meet the needs of the community. This involves architectural components adopted from TOGAF [33] described in the following.

a. Business components include architectural models of city operations and process, looking specifically at shared and complementary services that motivate the community and how the city is organizationally structured.
b. Information system components capture architecture models of IT systems, looking at mutual applications and data that serve the community.
c. Technology components including architectural technology that are used to implement and realize information system solutions.
d. Thus, by defining EA blueprint, we aim to shape value co-creation foundation toward city service design. The refined EA serves as the backbone of smart cities, ready to effectively meet community needs and objectives, and to facilitate the implementation of innovative initiatives in the next stages of service design and implementation.

Phase 4 is designing city services. The smart city transitions from structural planning to service design, building on the solid foundations established during the EA phase. The primary objective is to create and refine specific services that respond directly to community needs and align with city actor's preferences and expectations. Phase 4 ensures alignment between service design, architectural blueprint, and the co-creation strategies.

Phase 5 is implementing smart services. The services designed are prototyped, implemented and deployed within the community during this stage. It is about implementing the planned services and making them available and accessible to community actors. This stage marks a milestone where the smart city moves from service design to the concrete implementation of innovation through smart services. Implementing the city services designed to improve city actors' engagement and inclusivity. This phase requires comprehensive integration planning for intelligent technologies, such as machine learning and artificial intelligence, into existing service frameworks. Pilot implementations are an important step, enabling the smart city to validate the effectiveness of selected smart services in real-life scenarios.

Phase 6 is evaluation and continuous improvement. During this phase, the co-created values are assessed, this includes not only the tangible generated value but also the feedback received from the community and its engagement. Moreover, areas of improvements are identified, as well as how previous phases were achieved, feedbacks and lessons learned by the various city stakeholders [60]. Establishing measurable KPIs is a central point, enabling the smart city to regularly assess the success and impact of co-creation initiatives. The adaptability and iterative nature of this phase is important, as strategies are refined based on continuous feedback and evolving community dynamics.

In this way, the smart city works to adapt to the changing context of the community and align its strategies to remain pertinent. By returning to an initial phase of understanding of the community, this phase serves as a crucial bridge for the future co-creation cycle. Continuous improvement initiatives, rooted in community interactions, cultivate a culture of innovation. This involves ongoing communication and collaboration between actors of the community. The feedback received is used to iterate and improve the services continually, ensuring they remain responsive to the evolving needs of the smart community.

The outputs of the presented process conduct a novel architecture-based approach, which involves giving federal guidance and designing the overall blueprint of smart city toward value co-creation in smart city. The development approach serves as a blueprint outlining the structure and design principles which guides the development of smart services according to the community's requirements, and highlights standardization, and continuous improvement. The transitional evolution of smart city into a smart community motivates digital transformation of urban area. This implies a community that benefits from strategic and customized services, actively engages in co-creating value, and experiences positive outcomes because of the implemented co-creation initiatives.

5. EXPERIMENT

This section introduces a smart parking case study and presents the applied method to simulate the EA based value co-creation approach. It aims to evaluate improvements in interaction and collaboration among members of the parking community. To achieve these goals, two main experiments were conducted to simulate the impact of different configurations and strategies on system latency and the number of processed entities served.

5.1. Case study

Studies have shown that 30% of traffic congestion in cities is caused by drivers who spend time searching for a parking place [61]. In fact, it is important for citizens and visitors to find a parking spot in a smart manner. A smart parking system that is well-designed reduces the time and frustration of parking searches, while also improving traffic flow and reducing congestion. Thus, the result is a more accessible and organized urban environment that benefits both residents and visitors.

The background and the context of our study comes from a public description of the Ettelbrück smart parking in Luxembourg [60], [62]. The project uses smart parking technology with the aim of making the city smarter and enabling real-time monitoring of parking spaces for different drivers' groups, including people with reduced mobility, electric vehicles, delivery drivers and taxis. The objectives are to reduce parking times, CO_2 emissions, vehicle operating costs and air and noise pollution [60], [62].

According to our approach, by blueprinting co-creation effort toward value exchanges among city stakeholders, the design and implementation of smart parking system aim to reduce cruising times for drivers and improve urban mobility. The following description of steps stands on the proposed EA-based value co-creation methodology.

a. Phase 1: Community context identification: identify urban mobility challenges, with a focus on the significant time that driver’s community spend searching for parking spots.
b. Phase 2: Analyzing requirements and value co-creation opportunities: analyze the parking requirements and identify opportunities for improving parking services through collaborative value co-creation among the city stakeholders (authorities, parking managers, and service providers), to minimize parking search times, enhance system responsiveness, and maximize parking space utilization.

c. Phase 3: Defining EA blueprint: Develop an EA blueprint to guide the integration of smart parking components, based on the defined value co-creation opportunities among city stakeholders. This collaboration involves federating their required architectural components (services, data, applications, and technologies) to enhance smarter parking service design.
d. Phase 4: Designing city services: design smart parking services in a federative manner based on co-creation to achieve efficient and optimized parking management.
e. Phase 5: Implementing smart services: prototype and deploy the smart parking including sensors, payment systems, and mobile applications to provide drivers with real-time parking information, ensuring effective collaboration among city stakeholders.
f. Phase 6: Evaluation and continuous improvement: continuously evaluate system performance, focusing on reducing search times and optimizing the number of drivers served and reaching the parking spot, to iteratively improve smart parking services and adapt to evolving urban dynamics.

The main objective of this study is to evaluate the co-created value within the context of smart parking. This evaluation focuses on how co-created value can effectively reduce latency in locating available parking spaces. Furthermore, it analyses how this value can increase the overall service by maximizing the number of drivers served, ultimately improving system efficiency and user experience.

5.2. Material and parameters

This sub-section explains how simulation can be used to evaluate the quality of the proposed approach. To conduct this evaluation, we use SimEvent software along with a Simulink model to simulate the smart parking system. Through this simulation, we can illustrate various aspects of our approach allowing for a comprehensive assessment of its performance and identifying areas for enhancement.

The simulation framework provided by SimEvents software is used to analyze event-driven model and improve performance features like response latency, operational workload, entity loss, and conversion metrics, using a modeler and simulation engine with a MathWorks component library. Various blocks like servers, queues, and generators are employed to develop discrete-event systems within the Simulink simulation. The blocks are employed for creating and handling the studied entities.

In our study, the entities can include vehicles entering and leaving the parking lot, available parking spots, and time-stamped parking sessions. By using blocks, we can model several significant elements of the architectural system, like processing latency, prioritization, routing, and scheduling tasks. Our principal focus in this study is to evaluate latency and the number of served entities improvements to optimize cruising time for drivers and decrease mobility congestion in smart city. In this system, entities represent drivers, and servers represent services used in a classical and federative manner. The federative approach is based on co-creation integrating contributions from various city stakeholders and facilitate their interaction and collaboration. The system's state, like entity services or queue lengths, is changed based on updates in entity attributes, which correspond to asynchronous events.

In the experiments implemented in this study, we are considering the following parameters and conditions. n is the number of servers that represent the parking system service (S). l is the latency or average queue length, defined as the accumulated time-weighted average queue. t is the time between the entity arrival and/or the number of departure events per server. t_f is the total time-weighted queue of the total number of entities. f is the total number of entity arrivals served between t_0 and t_f. To compute the latency l, the formula (1) was used [63].

$$l = \frac{n}{t_f} \sum_{i=1}^{f} q \times t \quad (1)$$

where q is the size of the queue per server and $t = t_i - t_{i-1}$ is its duration. For the simulation we consider $i = 1$, $t_0 = 0$ and $t_f = 100$.

5.3. Experiment setups

Two experiments are used to conduct the simulation. In the first experiment, the performance (system latency) was experimented by augmenting the number of servers. The second experiment represents our federative approach, which consists of creating a model based on the co-creation of different services to improve the latency and the efficiency of serving incoming entities. In the first experiment, we investigated the effect of resource allocation on system performance by varying the number of servers for the same service in Figure 5. Two simulation models are experimented, one with three servers ($n = 3$) and another with seven servers ($n = 7$).

Our second experiment focuses on introducing the proposed EA-based value co-creation model, which is founded on working together and interacting with various city actors to enhance service delivery for drivers in Figure 6. The simulation model combines multiple servers that work together to speed up entity processing and delivery. In this simulation, we used 3 different service blocks S_1, S_2, S_3. The number of servers in each service block was $n = (n_{S_1}, n_{S_2}, n_{S_3}) = (2, 2, 1)$.

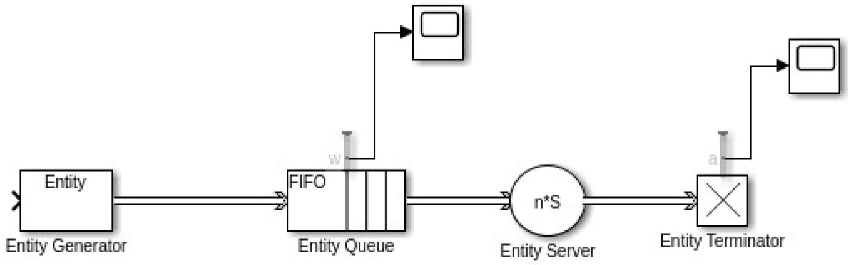

Figure 5. Simulation model of experiment 1

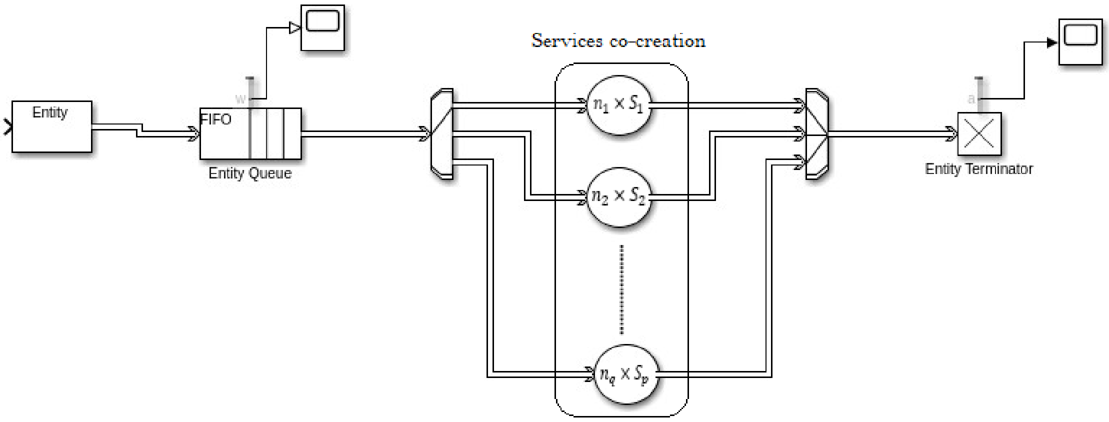

Figure 6. Simulation model using o-creation for experiment 2

These simulation models enabled us to evaluate the impact of different configurations and strategies on system latency to find parking spots and enhance the number of processed entities served. These last represent the served drivers. The simulation model allows us to evaluate the impact of different configurations and strategies on system latency when searching for parking spots and the number of processed entities served.

6. RESULTS AND DISCUSSION

6.1. Evaluation and results

The results of the first experiment demonstrate a slight improvement in latency as the number of servers increases from $n = 3$ to $n = 7$, highlighting the importance of resource investment in enhancing waiting time to find a parking spot in Figure 7. Our second experiment focuses on introducing the proposed EA-based value co-creation model, the simulation model integrates multiple servers that interact to facilitate quick entity processing and delivery. In this second experiment, we observed that the latency values dropped to less than 6 units compared to the considerably higher latency observed in the first experiment, which is tangible at l =20 in Figure 8.

By comparing the performance of the second experiment with that of the first one, we observe an important reduction in latency, indicating the effectiveness of our EA-based value co-creation approach in improving city service performance and resource use in Figure 8. Also, the proposed approach demonstrates an important increase in f the number of processed entities representing drivers and successful allocations, highlighting its potency in optimizing parking allocation and enhancing system scalability and efficiency in Figure 9. Table 4 shows the values obtained with parameters considered in these experiments to better highlight the comparison.

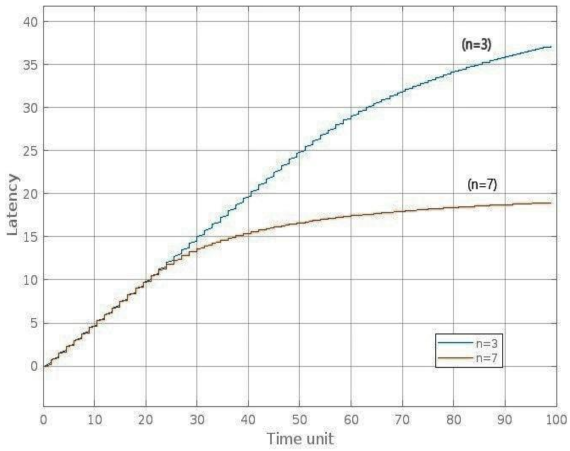

Figure 7. Latency results from experiment 1

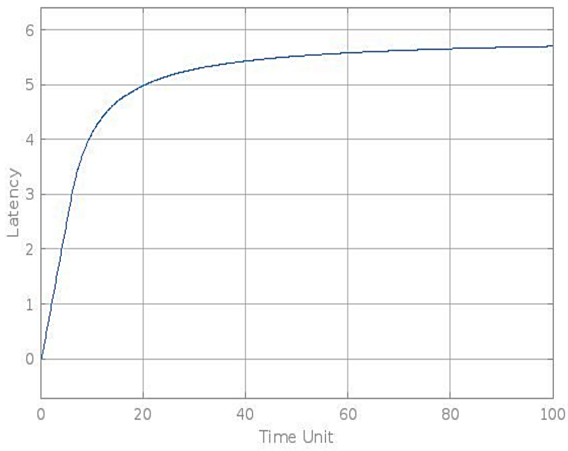

Figure 8. Latency results from experiment 2 using the proposed co-creation approach

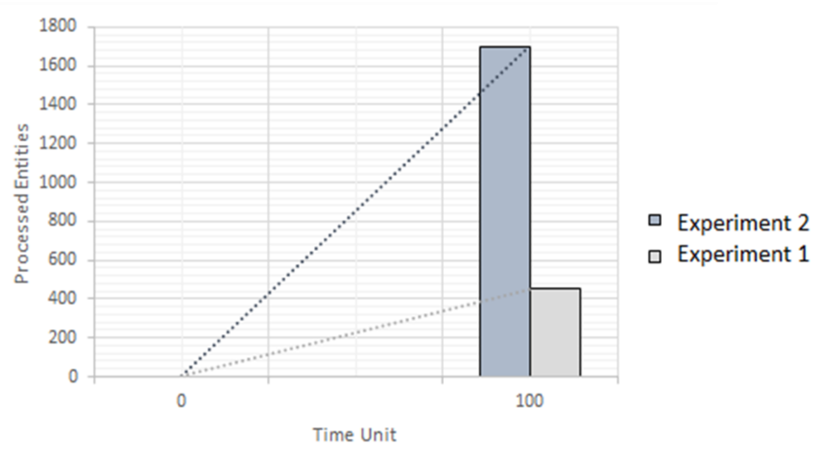

Figure 9. Number of processed entities and arrived at finish for experiment 1 and 2

Table 4. Summary of experimental results

	Experiment 1 (a)	Experiment 1 (b)	Experiment 2
t_f	100	100	100
n	3	7	(2, 2, 1)
l	37	18	5.7
f	-	≈480	≈1700

6.2. Discussion

The results of the simulation within the EA-based value co-creation approach reveal its performance in the context of smart parking. On the one hand, it enables a significant reduction in latency, illustrating the amelioration of the waiting time for finding a parking spot. On the other hand, the important increase of served drivers and successful spot allocation highlights the power of collaboration between city shareholders and its ability in identifying and addressing city inefficiencies. Through blueprinting city actors' co-creation, optimization tracks are identified, and suitable, win-win solutions can be implemented. The proposed approach's adaptability and scalability are highlighted during experimenting different configurations, which enable continuous enhancement of the smart parking context.

7. CONCLUSION

Digital transformation is increasingly indispensable for cities to effectively deliver smarter services. Our study presents an integrated EA-based approach highlighting value co-creation to overcome the existing smart city challenges, enhance engagement, and develop impactful smart services aligned with the urban context. This work provides a step-by-step methodology to enhance collaboration, city services, and community engagement within smart city frameworks. The evaluation of the proposed approach in optimizing smart parking, particularly in reducing wait time for drivers, underscores its practical benefits for the community. Our next research will explore its effectiveness in advancing urban sustainability through new case studies, aiming to validate its applicability and benefits across different smart city initiatives.

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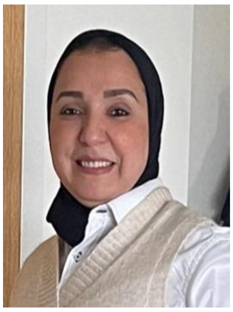

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