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A Framework for adapting Digital Twin approaches for Knowledge Management in Public Services

Mariia ERSHOVA, Viktor MALAKUCZI, Luca D'ELIA and Lorenzo IMBESI[a]

[a] Sapienza University of Rome

Digital Twins are playing an increasingly important role in various industries. At the same time, there is a process of digital transformation across public services, the success of which is related to the quality of Knowledge Management in organizations. The study aims to understand how Digital Twin can enhance Knowledge Management in the Public Sector. Although Digital Twin has already demonstrated its potential in Smart Buildings, Cities, and Industries, there is a lack of results regarding its successful application in the Public Sector. To explore the potential of Digital Twin technologies for public services, this contribution offers an Integrative literature review and describes the creation of the Service Design in the project on Digital Twin of the Public Building. It was found, that only a few studies delve into the use of the Digital Twin in the Public Sector leaving a gap for Service Design with its consolidated methods and a Human-Centered approach. Therefore, this study proposes a new framework for building relationships between concepts of Knowledge Management in the Public sector, Digital twin, and Service design. The latter in a given system is necessary to create a dialogue between stakeholders, experiences, and interactions among them and technology.

***Keywords**: Digital transformation; Information Resources; Public sector; Public administration; Service Design*

Introduction

Digital Twin (DT) helps to effectively plan and optimize processes in the industry, but in the future, this approach can be also powerful beyond manufacturing (Kaivo-oja, Knudsen, Lauraeus & Kuusi, 2020). Could it be useful for improving the Public Sector as well, and in particular, its Knowledge Management? Some studies already highlight the need for government agencies to initiate feasibility studies on the use of Digital Twins in their areas (Rasheed, San and Kvamsdal, 2020).

The term Digital Twin has been anticipated by David Gelernter since 1991, then formally conceived by John Vickers (Piascik et al., 2010) almost 20 years later, and in recent years, numerous articles can be found mainly in the literature on the field of industry, smart cities, and smart healthcare (Yang, Karimi, Kaynak & Yin, 2021). Moreover, several advantages of DT approach can be used to empower knowledge, such as exploration of a range of scenarios, forecasting problems, future planning, optimization of solutions and so on (Singh et al. 2021).

Knowledge is power and when managed effectively it produces positive results (Rao, Chaudhary and Goswami 2019). As specified by UNESCO, “Knowledge Societies are societies in which people have the capabilities not just to acquire information but also to transform it into knowledge and understanding, which empowers them to enhance their livelihoods and contribute to the social and economic development of their communities” (Engida, 2016).

Thus, Knowledge Management is becoming one of the necessities for the Public Sector, and this is already highlighted as an area of research of increasing importance (Massaro, Dumay and Garlatti, 2015).

At the same time, Kaivo-oja, Knudsen, Lauraeus & Kuusi (2020) affirm that the application of DT approach for effective Knowledge Management in organizations can be done only through fruitful synergies between human beings and machines. Therefore, there is a need for resources that can think out these interactions, such as a Service Designer who has both Human-centric design and Human-Machines Interaction approaches.

On the base of this background, the research states the following: Digital Twin can enhance Knowledge Management in the Public Sector and for its effective application the Service Design should be used.

To confirm it we conduct the Integrative literature review based on 40 articles on this emerging topic, which reviews, critiques, and synthesizes selected literature available to date to generate a new framework (Torraco, 2005). To carry out a critical analysis we needed to deconstruct this topic into its basic elements: Digital Twin, Knowledge Management, and Service Design, which were the main keywords for the literature search. To investigate the DT approach, we started with already existing research in the Public Sector, then analyzed it in other fields: Smart Buildings, Cities, and Industries, and in the end, evaluated its impact on environmental, social, and economic sustainability. After, Knowledge Management in relationships with the Public Sector and with Digital Twins was examined. Moreover, we described the role of Service Design in the implementation of the Digital Twin, as well as showing our workshop with stakeholders involved in the Digital Twin of the Public Building. This leads to the preliminary conceptualization of the DT approach for Knowledge Management in the Public Sector and the role of the Service Designer through a new framework.

Digital Twin in the Public Sector and other fields

The Digital Twin is a virtual representation of a physical asset that can be used for better decision-making, real-time prediction, optimization, monitoring, and controlling via data (Rasheed, San and Kvamsdal, 2020).

The idea of a Digital Twin appeared even before its popularity, namely in 2002 by Grieves, who came up with the “Mirrored Spaces Model” connected with Product Lifecycle Management and including the real space, virtual space, and a mechanism for connecting the data flow between them. The name Digital Twin itself was created by NASA for their flying vehicles in 2010 (Singh et al., 2021).

The DT approach is based on cyclical flows occurring through a series of three steps, shown in the Figure 1, collectively known as the physical-to-digital-to-physical cycle (Kaivo-oja, Knudsen, Lauraeus & Kuusi, 2020), which are:

1. physical to digital - taking information from the physical world and creating a digital record from it;
2. digital to digital - sharing information and discovery of meaningful insights through advanced analytics, scenario analysis, and artificial intelligence;
3. digital to physical - application of algorithms to translate decisions to stimulate changes in the physical world.

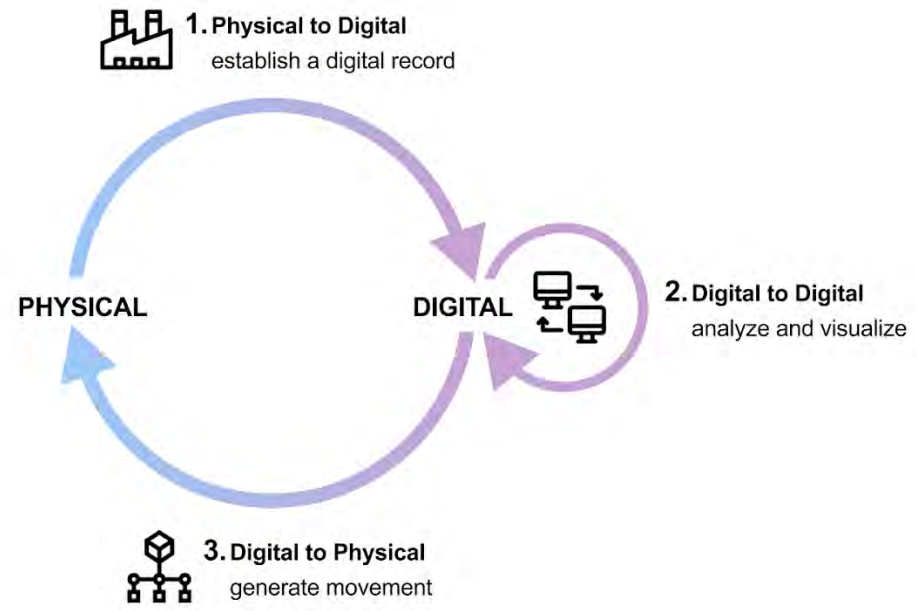

Figure 1 The physical-to-digital-to-physical cycle. Source: Deloitte (2024, p. 03).

Research into technical solutions to the Digital Twin is mainly focused on leveraging existing technologies that include Artificial intelligence, 5G, Internet-of-Things (IoT), wireless, RFID, Ethernet, actuators, and the cloud (Jones, Snider, Nassehi, Yon & Hicks, 2020). The study even if touches on some of these DT technologies, mostly focuses on the DT approach and DT solution that as we state, is applicable in various fields, not just Smart Buildings, Cities and Industries. Under the DT approach, we mean a broad concept that based on the theoretical framework and methodology for creating and using DT. While the DT solution we intend the practical application of the DT approach to achieve specific goals in a defined context. For example, the DT solution can be Digital Twin of new innovation center Rome Technopole, which is described later in the article, for energy and the water cycle management.

To understand why the DT approach can be helpful in the Public Sector, it is crucial to point out the benefits of using DT in different areas, such as in industry (Singh et al. 2021).

- Acceleration of prototyping and product redesign through several scenario options proposed by virtual twins.
- Economic benefit, since it uses mostly virtual resources.
- Forecasting problems and planning the system in future states of the physical twin.
- Optimization of solutions as the DT allows exploration of a range of scenarios.
- Accessibility due to the ability to manage and monitor a physical device remotely.
- Reduce material waste for modeling and testing prototypes of products or systems.
- Consolidating documentation and communication around the DT in one place, for example, data scattered across different software applications, databases, etc.

Digital Twins in the Public Sector

The following is a literature review covering an understudied topic, the use of the Digital Twin in the Public Sector, for that reason not only existing research and case studies in this area will be considered, but also the applications of the DT approach in other areas. The collected research and case studies are grouped into Public sector, private sector, and public and private sectors.

Starting from the Public sector, it is important to underline, that digital transformation is a necessity for public organizations, and even if some government functions have made significant progress in this area, the full potential of digital transformation remains untapped (Alvarenga, Matos, Godina & Matias, 2020). Few studies already demonstrate the potential of the DT approach in the Public sector, that cover the concepts of using it to improve bureaucracy and public policy.

Eom (2022) speaks about a Digital Twin bureaucracy, defined as a digital replica of a bureaucracy in the physical world. It is based on the data and new information and communication technologies (AI, IoT, and cloud computing) and will make autonomous decisions on matters of government affairs. To demonstrate the benefits of the Digital Twin bureaucracy, Eom compares it with the Weberian bureaucracy.

- In the last one, the officials are hired and promoted based on merit-based objective criteria, while in the Digital Twin bureaucracy, they are replaced by data scientists.
- In the Weberian bureaucracy, the bureau is administered according to a limited set of procedures and rules, instead in the Digital Twin bureaucracy it is replaced by codes and algorithms.
- Finally, in the Weberian bureaucracy communications and information in the bureau are managed by "papers in motion", rather Digital Twin bureaucracy is a world of “data in motion” operated through digital elements (codes and algorithms) and digital infrastructure (platforms and cloud systems).

Another article explores the use of DT technologies in public policy-making, looking at a scenario for a public bike-sharing system. Its outcome underlines the advantages of the implication of DT simulation scenarios modeling to make intelligent public policy decisions (Hwang and Choi, 2023). It is important to highlight that these two studies above were done for Sejong City in South Korea.

Digital Twins in Smart Buildings, Cities, and Industries

Apart from these studies on the use of the Digital Twin in the Public Sector, nothing was found, nevertheless, many projects, that actively use DT technologies, involve both public and private sectors, such as smart healthcare and smart cities. In healthcare, DT solutions are most popular in personal health management and precision medicine, while in smart cities in agriculture, urban transport, urban health management, and security (Yang, Karimi, Kaynak & Yin, 2021). In particular, some cases of smart cities and smart buildings, that potentially can be interesting for the Public Sector, are described below.

The Docklands area in Dublin, Ireland uses a Digital Twin smart city for citizen feedback, the 3D model of which can be published online for citizens, where they can give their feedback on planned changes in the city, and can also interact with components to mark problems in their area. Unity3D software was used to load the DT with a 3D model having three layers of terrain, buildings and infrastructure; as well as pedestrian mobility models to simulate crowds with different types of agents. The DT solution facilitates the dissemination of information and provides transparency to the public before decisions are put into practice (White, Zink, Codecá & Clarke, 2021).

The Shanghai East Hospital benefits from a “continuous lifecycle integration” method based on the concept of DT, which helps its managers obtain the detailed status of the whole hospital and receive timely facility diagnosis and operation suggestions that are automatically sent back from the digital building to reality. This case study has implemented continuous integration of static and dynamic data of several management systems from the design phase until the operations and maintenance phase, followed by developing a DT software system with real-time visual management and artificial intelligent diagnosis modules. After one year it has already achieved the desired sustainability performance by reducing energy consumption, avoiding facility faults, reducing the number of requested repairs, and enhancing the quality of daily maintenance work (Peng, Zhang, Yu, Xu & Gao, 2020).

The Capital Projects can benefit from a Financial Digital Twin, that integrates fund allocation, project execution, and rules-based knowledge management in real time. This Financial Digital Twin was designed based on DT, automated rules-based checking, BIM-based visualization, and analysis concepts. This automation ensures compliance and optimizes the use of financial data throughout the asset lifecycle (Lynch, Issa and Anumba, 2023).

The following describes potentially useful for the Public Sector case studies from industry, specifically from the private sector.

- Twinzo created a Digital Twin of smart offices in buildings in London, Bratislava, and Budapest, which allows forecasting future behaviors by using predictive analytics and machine learning algorithms on data collected from sensors throughout the facility or process. In particular, it is also used to monitor the movements of employees and visualize the occupancy of desks and rooms and data from the environment. The last functionalities besides daily needs can be used in emergencies, for example during a fire alarm, in a way that security workers can understand where workers are in the office for their evacuation (Twinzo, 2023).
- Kroger Co. and NVIDIA envision applying the Store Digital Twin to identify early indicators of deteriorating freshness through computer vision and analytics, use dynamic routing for last-mile delivery to ensure freshness, and optimize store efficiency and processes with DT store simulation, for example removing cashiers and adding self-service lines (NVIDIA Newsroom, 2024).

- Azure Digital Twins helps to optimize supply chain efficiency by providing real-time tracking, actionable insights and flexible modeling through open modeling language to create custom domain models of connected environments, live execution environment to bring the DT to life in a live graph representation, and input from IoT and business systems to connect assets (Microsoft Azure, 2020).

Having analyzed various studies on the integration of the DT approach in different fields, it is also significant to understand what impact this process has on sustainability from all its aspects.

Impacts of the Digital Twin on environmental, social, and economic sustainability

As highlighted by the Sustainable Development Goals, there is an urgent need to harmonize environmental, social, and economic progress that should be taken into attention while applying the Digital Twin as one of the disruptive technologies of Industry 4.0.

Environmental sustainability is already on the basis of different DT projects. For various Public Buildings, such as train station buildings in London, one of the main objectives of DT technologies is to calculate the environmental impact of the building, such as carbon dioxide emissions (Kaewunruen and Xu, 2018). In larger scale projects, the Digital Twin of a Positive Energy District provides a revolutionary way to accelerate the sustainable development of society in terms of the energy transition, circular economy, and climate change (Zhang et al., 2021). At the same time, in industry, the DT approach can serve to improve the sustainability performance of entire value chains of production complexes thanks to its sustainability-oriented decision support (Barni, Fontana, Menato, Sorlini & Canetta, 2018).

The social and economic sustainability can be influenced by the workforce's acceptability of DT technologies and their fear of losing their jobs, although automation only results in job redistribution without much impact on employment (Sheridan, Vámos and Aida, 1983). It highlights the need to develop new skills during employee training that will facilitate mastery of new technologies. The important role of humans in interacting with technologies that have Artificial Intelligence is not only the coordination of Artificial Intelligence developments but also the verification of Artificial Intelligence results, which, in general, will allow employees to focus on more creative work. As the world moves towards greater autonomy through digital transformation, efforts must be made to create opportunities for all participants in society. To ensure this, policymakers need to work on inclusive policies and regulations to democratize technology (Rasheed, San and Kvamsdal, 2020).

Thus, the DT can be considered unique in the development of Public Sector buildings and in other interventions in this area for different reasons.

- The DT can optimize construction and operational processes, reducing public resources, especially the costs, carrying out a continuous assessment of the state of construction and system efficiency, as in the case study of the DT of the Shanghai East Hospital (Peng, Zhang, Yu, Xu & Gao, 2020).
- The DT can help improve public policy and decision-making through the data-driven approach and scenario analysis, ensuring the purposefulness and effectiveness of state investments, as in the case study of the DT for public policy-making (Hwang and Choi, 2023).
- The DT can enhance public participation and transparency via interactive models for the public, thus including them in the decision-making, contributing to the transparency and democratization of technology, as in the case study of the DT of smart city for citizen feedback (White, Zink, Codecá & Clarke, 2021).
- The DT can reinforce sustainable development, optimizing the use of resources and monitoring the environment to comply with environmental norms, as in the case studies of the DT of train station buildings (Kaewunruen and Xu, 2018) and the DT of a Positive Energy District (Zhang et al., 2021).

Discussing the state-of-the-art of the DT approach in the Public Sector and other fields, as well as its Impacts on environmental, social, and economic sustainability, it is necessary to proceed with another element, Knowledge Management, starting from its definition and preceding with how it relates to the Digital Twin and the Public Sector.

Knowledge Management in the Public Sector and Knowledge Management through Digital Twins

Knowledge Management is understanding and beliefs in an organization about it and its environment (Nonaka and Takeuchi, 1995). The knowledge can be: explicit - codified, easily translated, and shared facts and information in the form of reports and other documents, and tacit - personal knowledge that is hard to confirm and share with others about issues, solutions, services, and others.

Some studies confirm that Knowledge Management is a critical factor in the success of digital government (Alvarenga, Matos, Godina & Matias, 2020), in particular, it is significant in enhancing governments' competence, raising governments' service quality, and promoting the healthy development of e-government (Zhou and Gao, 2007).

To understand precisely how the Public Sector can get these benefits, a Knowledge Management conceptual model described by Zhou and Gao (2007) is considered and used after as a structure for the new framework. It consists of a knowledge-collection subsystem, a knowledge organization subsystem, and a knowledge application subsystem.

1. Knowledge-collection subsystem is the basis of Knowledge Management and includes three processes of knowledge management: knowledge recognition, knowledge acquisition, and knowledge accumulation.
2. Knowledge organization subsystem orderly processes knowledge and consists of knowledge classification, knowledge depot, and knowledge map.
3. Knowledge application subsystem is an output system, that combines the results of the other two subsystems to make an interface to various users. This subsystem includes knowledge sharing, knowledge exchange, and knowledge creation.

To build the new framework is crucial to understand the relationships between Knowledge Management and Digital Twins. The research of Kaivo-oja, Knudsen, Lauraeus & Kuusi (2020) tries to answer the question of what is needed for effective Knowledge Management in organizations when the DT and Industry 4.0 approaches are applied. It was emphasized that the most critical issue in this process is the synergies between human beings and machines.

Namely, the system integrations must be based on

1. the understanding of Human-Machines interactions,
2. the understanding of learning processes in organizations,
3. the understanding of leadership (based on Leadership Theories), Human Resource Management Systems (based on Human Resource Management theories), Information and Data Management Systems, and Web-engineering (based on information engineering and information theory).

Therefore, there is a need for resources that have the capacity to build these communications and interactions, which can be provided by Human-centric design and Human-Machines Interaction approaches.

Service Design in the Public Sector

Thus, the literature review covers its last element, Service Design, which has the ability to face complexity and create flexible solutions. As Manzini states, the role of a designer, within social innovation initiatives, might function as an expert, triggering and facilitating various design conversations (Manzini, 2015).

Several governmental organizations are already interested in using Service Design methodologies for the Public Sector, such as Design Thinking and Co-design. For example, Design Thinking has helped some public managers explore new methods for the creation of policy (Mortati, Schmidt and Mullagh, 2022).

The progressive diffusion of digital services offers a chance to simplify government operations, such as the Italian Login project that aims to introduce the Design Thinking and Service Design methodologies into Italian public administration. These collaborative and open-source models present an opportunity to reconsider public service communication in a context that encourages sharing between public managers and designers for public goods (Sinni, 2017).

At the same time, it is necessary to understand the limitations of some approaches, for example, in technology-oriented design, the focus of designer can narrow to user-centered approach, which limits their role to user advocate. This approach can have the following disadvantages: it treats users as nothing more than users, and it fails to consider potential harms and systemic forces. While Systems thinking can focus on a broader vision,

namely: interconnectedness - the interdependence between everything, including external actors such as stakeholders and the regulatory environment; causality - consideration of intended and unintended consequences; and wholeness - holistic thinking about the system (Cababa, 2023).

Returning to the Service Design, its methods for digital services can help to deal with particular issues such as Human-Machines Interactions, which have already been confirmed in several domains such as well-being, healthcare, and relationship breakdowns. Namely, Service Design methods, such as stakeholder maps, user journeys, and business model canvas, are already used for Human-Computer Interaction in different tutorials to develop services that are easy to use and have fluent and consistent user journeys (Colley and Häkkilä, 2018).

Despite these few practices of using Service Design in the Public Sector and for Human-Computer Interaction, there is no Service Design literature yet on the integration of the DT approach in this area.

Service Design for the Digital Twin of the Public Building

To better understand the role of Service Design in the integration of DT approach, it is important to apply it to specific projects. At the time of writing, we are working on a Service Design of new innovation center Rome Technopole with a Digital Twin for energy and the water cycle. This project will contribute to the Public Sector as a scalable case that is integrated into the Positive Energy Districts system, which is one of the strategic components according to the European Union for environmental sustainability (SET-Plan Working Group, 2018).

To create the Service Design, we held a workshop with engineers working on implementing a DT solution to manage energy flows (electricity and air conditioning), developing and testing the software. Specifically, the main KPIs that the general system must achieve are monitoring and forecasting of electricity consumption, air quality, thermal comfort, space occupancy, and photovoltaic production.

The workshop with engineers lasted 5 hours on the digital collaboration board and was aimed at understanding how stakeholders interact with the DT technologies and among themselves. To do this, we started with an introduction of what is Service Design and the first task was to understand who the stakeholders and users of this system and what access they have to the Digital Twin. Next, what key scenarios around the DT solution do they can imagine. Finally, based on these two, we tried to detail the aspects of the system.

Service Design contains a variety of methods and tools. We decided to focus on three of them, that cover all stages described by Stickdorn and Schneider (2011): for explore stage - Stakeholder map, for create and reflect - Design scenarios, and for implement - Service Blueprint. The benefit of these tools for our workshop is that they all can be used at the beginning of the project and in addition, they all can consider the resource distribution that is very relevant to the project focused on sustainability.

A Stakeholder map (figure 2) represents various groups included in a particular service. We started with the list of all stakeholders and then mapped them depending on their interests and motivations.

After we created Design scenarios that are hypothetical stories investigating a specific aspect of service offering, we represented them as plain text and divided the scenarios into ordinary and extraordinary. To provoke the discussion we asked about “negative” scenarios that they could imagine.

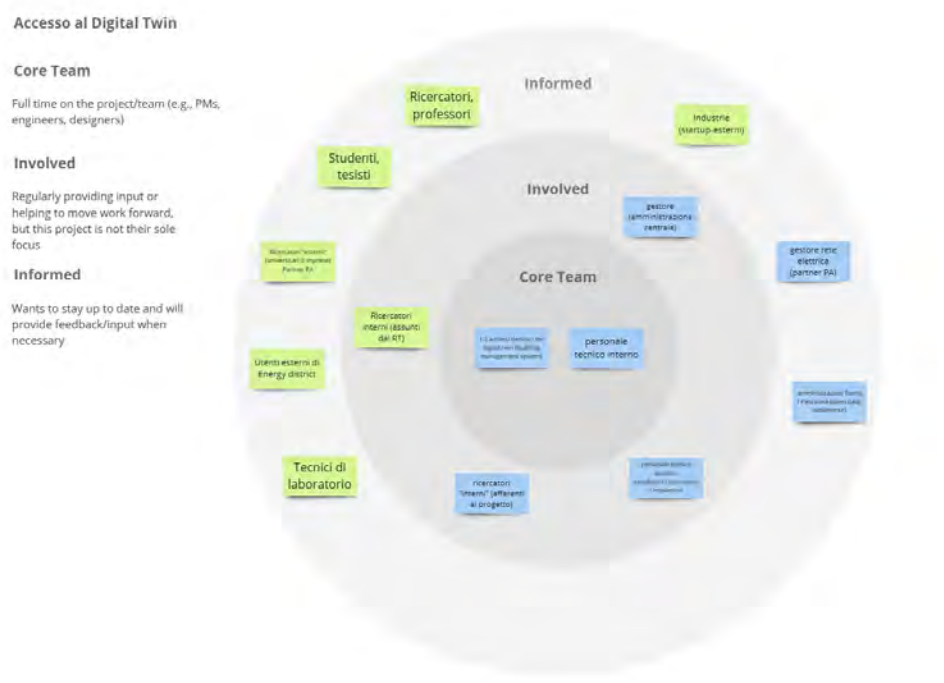

Figure 2 Stakeholder map with users in green and stakeholders in blue mapped depending on their access to the Digital Twin.

In the end, we demanded to fill in the Service Blueprint (figure 3), the tool to specify individual aspects of the service, that create perspectives of users, service providers, and other parties, starting from the customer contact and finishing in the behind-the-scenes processes. It is important to note that the tool has been slightly modified, as "Technology" raw has been added to both the front and back stages, and the tool focuses not only on the user's experience but also on the experience of stakeholders.

The results of the workshop were the identification of 7 types of users and 7 types of stakeholders of the building, which were located in the degree of their involvement and access to the DT system. This fairly large number of participants highlights the need for a Service Designer to plan their experience and interactions. In terms of Design scenarios, 4 ordinary scenarios were found that in the end, were aimed at the "positive" aspects of the service, and 8 extraordinary scenarios, most of which turn to be "negative" scenarios. One of the ordinary scenarios was analyzed using the Service Blueprint, which was very difficult since the scenario assumed the autonomy of the DT solution. Therefore, we repeated the Service Blueprint starting with a specific stakeholder who actively collaborates with the DT system and examined their typical actions through interactions with Digital Twin, users, and other stakeholders.

In general, this workshop once again proved that one type of stakeholder sees the system only from the perspective of their role in the project, and the Service Designer can be the person who will collect these visions into an output useful for all stakeholders and all users. To get a complete picture of this project, we plan to conduct new workshops with other stakeholders and intended users. In addition, we are considering the use of other framework and visualization tools to look at the project from the point of view of Systems Thinking, namely iceberg diagram, 'future wheel' diagrams and STEEP framework recommended by Cababa (2023) or Gigamap and Stakeholders' matrix analyzed by Jones and Kijima (2018).

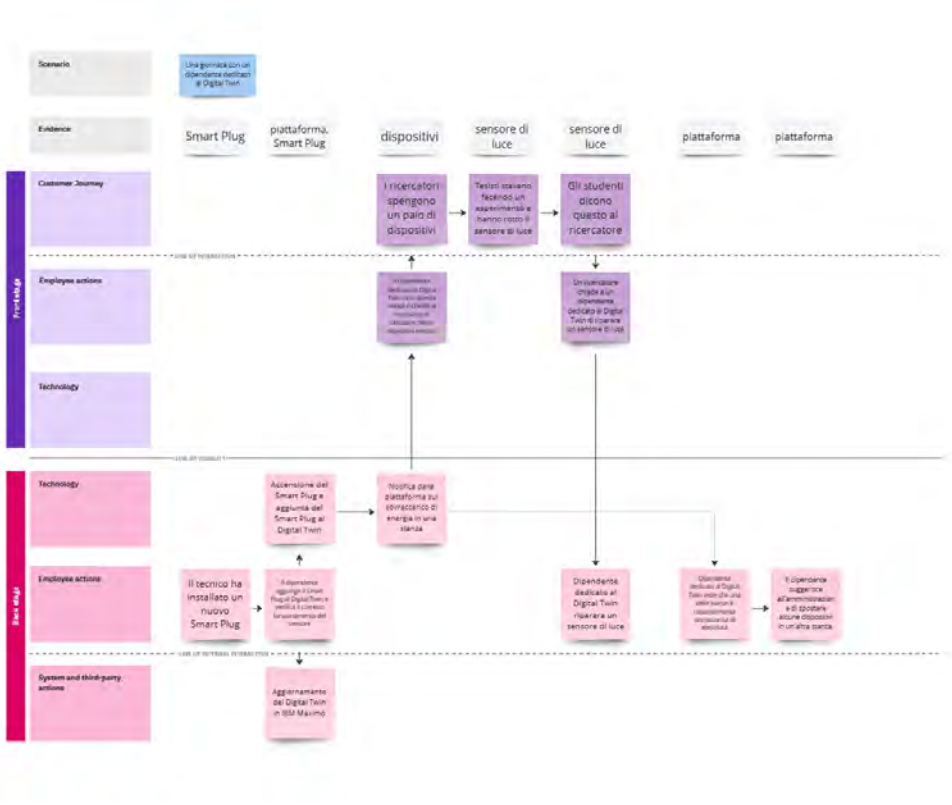

Figure 3 Service Blueprint focused on the employee dedicated to the Digital Twin.

Framework of Digital Twins for better Public Sector Knowledge Management and the role of Service Designer

The Integrative literature review finishes describing all its elements and to build the new framework, take as a structure the Knowledge Management conceptual model (Zhou and Gao, 2007) described above, adding possible functions the Digital Twin can offer. Tables 1, 2, and 3 represent the new framework, building relationships between concepts of Knowledge Management in the Public sector, Digital twin, and Service design. The tables consist of six columns: the first is the knowledge process in the Public sector from the conceptual model, the second is the possible DT function for this process (what), the third and fourth are DT process (how) and benefit (why) associated with this function, the fifth is a possible role of Service Designer while applying this DT function and the last one is the similar case study. The description of the DT function is inspired by the Golden Circle model (Sinek, 2009). In addition, it is important to point up, that the column DT process (how) emphasizes the problems that are mainly solved by engineers and the discussion further highlights the importance of the interaction between Engineering and Service Design disciplines.

On the first Knowledge-collection subsystem of Knowledge Management (table 1), the DT approach can improve knowledge recognition, and capture a wide range of data while accumulating it in a single place. At the same time, the Service Designer can help to decide what data is necessary based on the providers', stakeholders', and users' needs. These first interventions should be done before or during the DT application through design tools for explore stage and participant engagement.

Table 1 Knowledge-collection subsystem with DT approach and the role of Service Designer

Knowledge processes in Public sector	DT function (what)	Process (how)	Benefit (why)	Role of Service Designer	Case study with similar function
Knowledge recognition	Understanding the type of knowledge (explicit or tacit)	Through channel (e.g., explicit via documentation, tacit via comments) or patterns	Sorting of resources by knowledge type	Encouraging employees to share tacit knowledge (e.g., via a feedback system)	White, Zink, Codecá & Clarke, 2021
Knowledge acquisition	Capturing a wide range of data also from physical assets	Integrating data (e.g., about electricity consumption) from IoT system	Collecting information useful for regulating offices	Formulating data required by stakeholders	Peng, Zhang, Yu, Xu & Gao, 2020; Twinzo, 2023
Knowledge accumulation	Accumulating knowledge in one place	Cloud computing with a single database (with explicit and tacit knowledge)	Refusal of archives in favor of cloud computing	Formulation the stored knowledge required by stakeholders	Eom, 2022

On the second Knowledge organization subsystem of Knowledge Management (table 2), the DT approach can classify and organize knowledge, enhance knowledge resources dynamism, and create a map navigation system among them. At the same time, the Service Designer can help to decide what classification is needed and design intelligence resources and a navigation system for the DT platform. These interventions should be done before or during the DT application through design tools for explore, create and reflect stage.

Table 2 Knowledge organization subsystem with DT approach and the role of Service Designer

Knowledge processes in Public sector	DT function (What)	Process (How)	Benefits (Why)	Role of Service Designer	Case study with similar function
Knowledge classification	Classifying and organizing knowledge	Sort resources via criteria (e.g., keywords and meanings)	Help employees sort the knowledge through search	Formulation of the classifications required by stakeholders	-
Knowledge depot	Strengthening dynamic knowledge resources	Organized database (e.g., storing different resource versions over time)	Enhancing of dynamism of the knowledge resources	Design the intelligence resources required by stakeholders	-
Knowledge map	Help in creating and maintaining a knowledge map	Convenient navigation system (e.g., document tracking)	Quick finding of the necessary knowledge resources	Design the navigation system required by stakeholders	Microsoft Azure, 2020

On the third Knowledge application subsystem of Knowledge Management (table 3), the DT approach can provide a collaborative platform for knowledge sharing and exchange. In addition, DT technologies can anticipate potential problems and create and test solutions. At the same time, the Service Designer can help to encourage exchange and guide and review DT suggestions and solutions. These interventions should be done before, during, or after the DT application through design tools for explore, create and reflect, and implement stage and participant engagement.

Table 3 Knowledge application subsystem with DT approach and the role of Service Designer

Knowledge processes in Public sector	DT function (What)	Process (How)	Benefits (Why)	Role of Service Designer	Case study with similar function
Knowledge sharing	Providing stakeholders with an integrated sharing tool	The platform for knowledge sharing (e.g., for citizens' feedback)	Allowing employees and citizens to share ideas and experiences	Encouraging knowledge sharing and design of sharing platform	White, Zink, Codecá & Clarke, 2021
Knowledge exchange	Identifying and applying organizational structure and culture	The platform for knowledge sharing (e.g., notifying employees about relevant for them resources)	Help to use organizational culture to encourage knowledge-sharing	Co-creation of organizational structure and culture	-
Knowledge creation	Experimentation and testing of innovations	Virtual simulation and scenario analysis (e.g., of an increase in the number of employees)	Exploring new ideas and solutions from employees to stimulate innovation and creativity	Understanding problematic aspects, designing and testing solutions	NVIDIA Newsroom, 2024; Hwang and Choi, 2023
	Anticipating potential problems or failures	Advanced analysis (e.g., notifying about a new law contradicting an existing one)	Preventing failures and collapses	Design and testing solutions to potential problems	Peng, Zhang, Yu, Xu & Gao, 2020
	Optimization of new and existing solutions	Generative AI and platform with DT suggestions (e.g., proposals based on citizens' requests)	Expanding creative opportunities for new and existing solutions	Review of DT solutions required by stakeholders	Lynch, Issa and Anumba, 2023; Microsoft Azure, 2020

Discussions

Thus, as can be seen from the tables some knowledge processes are not yet sufficiently described by existing research on DT, namely Knowledge classification, Knowledge depot, and Knowledge exchange.

At the same time, the role of the Service designer in the process of enhancing Knowledge Management through the DT approach is described for each knowledge process in the table and overall it can be described through the following responsibilities.

- To open the dialogues between different stakeholders (managers, human resources, information, and data managers, engineers, operating staff, and others) and users of the DT system: encouraging them to share and exchange and creating organizational structure and culture, solutions, and others.
- To plan the journey of different stakeholders and users while interacting with the DT system physically or digitally, and understand their needs and pain points.
- To improve Human-Machines interactions, for example through creating targeting platforms for specific stakeholders and users with clear interfaces, navigation system of electronic knowledge resources, and sharing opportunities.
- To create/revise and test solutions from the point of view of the needs of stakeholders and users while efficient resource utilization.

Even though some of the functions and responsibilities of the Digital Twin and the Service Designer may overlap, such as problem-solving, it is important to note that the Service Designer, being a human, can better understand the needs and problems of people in the process and revise, complement and change the problems and solutions identified and proposed by the Digital Twin.

Coming back to our specific project on the creation of the innovation center Rome Technopole with a Digital Twin, the main Service Designer responsibilities should be to encourage the dialogues between different stakeholders, to design the journey of different stakeholders and users, and to improve Human-Machines interactions. These functions can be applied especially for new services, where there is a lack of real environment and users and stakeholders around the system.

From this project experience, and literature and case study analysis, it can also be concluded how the DT can facilitate a more integrated interaction between the disciplines of Engineering and Service Design. Initially, it is important to highlight the different tasks of these roles in DT integration, namely, Engineers use DT to model and analyze technical aspects of services, while Service Designers can use DT to visualize stakeholder journeys by testing different scenarios in a virtual environment. For both, DT's ability to provide real-time data allows for informed adjustments and improvements to service elements (Data-driven design). In this case, even if the tasks and backgrounds of the roles diverge, Engineers and Service Designers can complement each other, bridging the gap between technical development and User-centered design, resulting in more cohesive services.

Conclusion

The article describes the Integrative literature review and creation of Service Design for the Digital Twin of the Public Building to confirm how DT technologies can enhance Knowledge Management in the Public Sector and the significant role of the Service Designer in this process. The result of the study is a new framework describing 11 possible functions of the Digital Twin for various processes of Knowledge Management in the Public sector, and the 11 specific and 4 general responsibilities of the Service Designer. In general, Service Design in a given system is necessary to create a dialogue between various users and stakeholders, plan their experiences and interactions with each other and with technologies, and create and test solutions. In addition, these responsibilities were chosen specifically for the project in which the authors participated.

This research can stimulate sustainability, namely, it can lead to more efficient use of resources, including financial ones, in optimizing processes through better Knowledge Management. In addition, it can have an impact on the democratization of technology, as Service Design promotes inclusivity and stakeholder participation, ensuring that their needs are taken into account when designing DT systems. This approach promotes collaboration and transparency in the Public sector, improving service delivery and public good.

This research can be useful for Service Designers, Managers, Human Resources, Information and Data Management Roles, and Web-engineering specialists and will help them look at the application of DT technologies from an innovative and Human-centric point of view on different levels.

The disciplines that work directly with Knowledge Management can explore the use of the DT approach, especially in processes such as Knowledge classification, Knowledge depot, and Knowledge exchange, as shown in the tables there is a lack of case studies about this.

Future research will proceed with the development of the Service Design for the DT approach of the Public Building and can further experiment with the use of the Service Design methods for other public DT projects. Moreover, future studies could be aimed at creating recommendations for policymakers to develop inclusive policies and rules for democratizing the DT in public services.

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