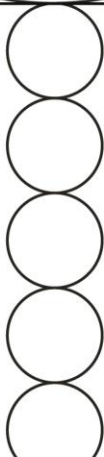
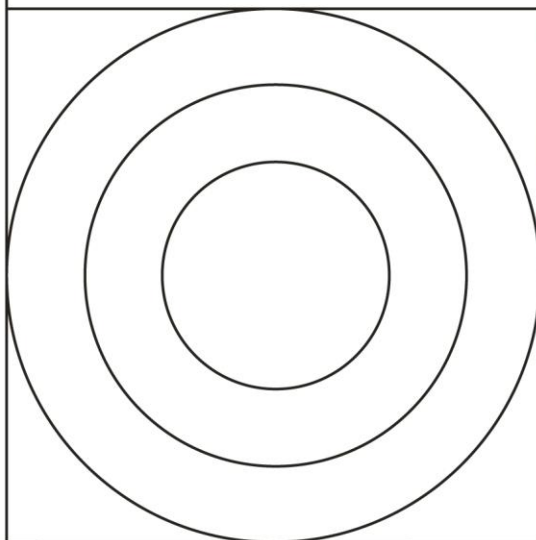
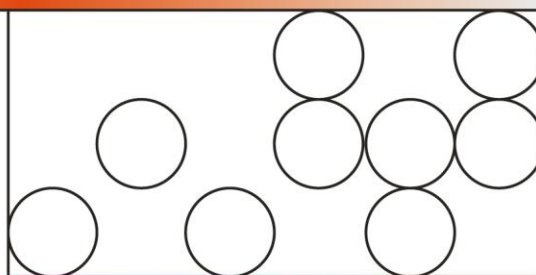
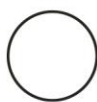


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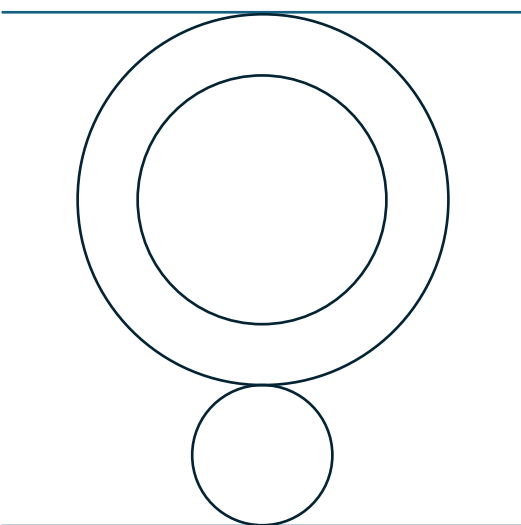
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[In]tangible

TABLE OF CONTENTS

[In]tangible interactions

7

KEYNOTE SPEAKER

F. Krupa. <i>Artificial Intelligence, Design Cultures, and the Future of Digital Practice</i>	10
Y. Peng. <i>Driving behavioural change: the role of data visualisation in optimising dormitory energy strategies</i>	20
A. Bassi, G. Ciliberto, M. C. Addis, J. W. de Denaro, M. Scotti. <i>Mapping Industrial Intangible Heritage: a Design-Based Approach</i>	32
M. Ershova. <i>Designing the future of Public Services: Digital Twins for Inclusive and Accessible Experiences through Service Design</i>	43
E. Polleri. <i>Tangible Interfaces for Intangible Experiences: the Role of the UX Specialist in the Software Development Team</i>	52
F. Petrocchi, L. Tinti. <i>Towards an Equal, Sustainable and Aware Multi-level Mobility</i>	64
I. Leggiero, C. Porfirione. <i>In/active. The Role of Design in the Creation and Transmission of Collective Memory</i>	72
R. Mercuri. <i>Heritage Landscapes – Interactions and Transition</i>	83

[In]tangible projects

96

KEYNOTE SPEAKER

M. Giannini, V. Pizzigoni. <i>A catalog in the shape of a map. Piranesi's and the Campus Martius</i>	100
F. Lucchi. <i>The possible Milan of Giuseppe de Finetti</i>	110
U. K. Škerl. <i>Imagination: public good is uberarchitecture</i>	119
I. Traeger, A. Delli Ponti. <i>Exploring the Seasteading Hypothesis: A Floating Utopia for the Techno-Solutionist age?</i>	130
4 E. Veronese. <i>An interdisciplinary model for the next nature-based city</i>	142

R. Varini, C. Amatori. <i>From public space to consumer space, or vice versa? Re-semanticizing places through design</i>	159
M. Cannata. <i>The Unfinished as Commons: material conditions for a deeper democracy</i>	170
F. Chen. <i>Assessment and Optimization of the Layout of Community Elderly Care Facilities from the Perspective of Health Equity</i>	183
Y. Chen. <i>Inclusive Urban Space Design through Nature-Based Solutions: Reflections and Insights</i>	194
C. Erdmann-Goldoni. <i>Conceptualizing a Data-Driven Platform for Public Space Revitalization: Integrating Tangible and Intangible Elements</i>	205
Z. Lou. <i>Regeneration and Optimization of Public Open Spaces, strengthening Tangible and Intangible Connections through Dynamic Strategies</i>	215
M. Manfroni. <i>Promoting local ecologies. Collective practices of symbiotic design</i>	226
G. Montanaro. <i>The Intangible Architectural Design Agency: Navigating the Tangible Construction Process of Public Space in Rural China. The Case Study of Zhaoshan Village</i>	238
D. Saladino. <i>Cooperatives and community maps: local development strategies for territorial enhancement</i>	249

Designing the future of Public Services: Digital Twins for Inclusive and Accessible Experiences through Service Design

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ABSTRACT

Digital Twins (DT) are already considered an important technology of Industry 5.0, but to fulfill their promises, DT's future development should prioritize human-centricity. In parallel, the Public Sector is undergoing digital transformation, with DTs emerging as vital tools in government feasibility studies. The article aims to understand how the DT approach may enhance social innovation, inclusion, and accessibility for citizens in the Public Sector.

While the human-centricity of DT in Industry 5.0 is extensively studied, there is limited focus on its application in accessible public service experiences. To explore the potential of DT in this area, this research offers an integrative literature review. It was found that only a few studies delve into the use of the DT for social innovation, leaving a gap for Service Design with its consolidated methods and a Human-Centered approach. Therefore, this study proposes a new framework Digital Twin Approach for Social Innovation in Public Offices through Service Design. The latter in a given system is necessary to engage stakeholders, design their journeys through (in)tangible interactions, and develop scenarios and prototypes.

DIGITAL TRANSFORMATION | PUBLIC SECTOR | SOCIAL INNOVATION | ACCESSIBILITY

1. Introduction

Digital Twins (DT) are already considered significant technological tools of Industry 5.0, but to fulfill their promises, Digital Twins' future development should find applications for improving human health and safety, work assistance and error reduction, training, and fair decision-making (Barata & Kayser, 2024).

In parallel, the Public Sector is undergoing digital transformation (Alvarenga, Matos, Godina & CO Matias, 2020), and its potential can be enhanced with the DTs.

The article aims to understand how the DT approach may enhance social innovation, inclusion, and accessibility for citizens in the Public Sector supported by Service Design.

Although DTs' human-centered priorities for Industry 5.0 are well-discussed in the scientific literature, there is still limited attention on their applicability for fostering inclusive and accessible experiences in public services. Some cases that are related to this question use DTs to improve user interaction with equipment (Tu et al., 2023), to collect citizen feedback for smart cities (White, Zink, Codecá & Clarke, 2021), and to guarantee universal accessibility to architectural heritage (Cruz Franco, Rueda Márquez de la Plata & Gómez Bernal, 2022), suggest the untapped potential for broader application in the Public Sector.

Design can promote inclusion and accessibility across digital technologies, as shown by numerous projects from product design to participatory design. Service Design, with its Human-centered approach makes it uniquely suited for addressing the complexity of public services and creating flexible solutions.

In order to explore the potential of DTs for social innovation in the Public Sector through Service Design, this research offers an integrative literature review (Torraco, 2005) that deconstructs this topic into two basic elements: Digital Twins and Design, which were the main keywords for the literature search. Starting from 46 articles, the paper concentrated on the 18 more related to this emerging topic.

2. Digital Twins in the Public Sector and Digital Twins for Social Innovation

Starting with the first element of the literature review, 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 & Kvamsdal, 2020).

Research into DTs emphasizes leveraging technologies like AI, IoT, 5G, RFID, and cloud computing (Jones, Snider, Nassehi, Yon & Hicks, 2020). This study focuses on the DT approach, a theoretical framework for developing DTs.

Digital transformation is critical for public organizations, yet its full potential remains untapped (Alvarenga, Matos, Godina & Matias 2020). Some studies already highlight DT's application in this field; for example, a Digital Twin bureaucracy uses autonomous decision-making to manage

government affairs (Eom 2022), while DT for public policy uses simulation modeling to optimize a bike-sharing system (Hwang & Choi, 2023).

Despite these studies about DT for the Public Sector, there is a noticeable gap in exploring how it can drive social innovation, inclusion, and accessibility. All these concepts deal with human-centricity: social innovation from the general point of view of the beneficial for society services (Murray, Caulier-Grice & Mulgan, 2010); inclusion from the value for all individuals without no one remains excluded (Saviano, 2025); and accessibility from the goal of universal access (Cruz Franco, Rueda Márquez de la Plata & Gómez Bernal 2022).

Because the implementation of DTs for social innovation in the Public Sector remains untapped, the paper brings as one of the examples Industry 5.0, where DTs already focus on human-centricity. While Industry 4.0 integrated advanced technologies like AI, robotics, and IoT to enhance productivity, it did not cover concerns about automation, job displacement, and the need for reskilling. Industry 5.0 shifts the focus from replacing humans to fostering collaboration, emphasizing human expertise alongside intelligent systems by optimizing workflows to alleviate stress, offering insights to make informed decisions, and creating virtual training environments to acquire new skills and others (Barata & Kayser, 2024).

Enhancing DT human-centricity requires designing both tangible and intangible interactions. Examples include integrating extended reality to improve user interaction with equipment (Tu et al., 2023), or other tools like natural language processing (Barata & Kayser, 2024), metaverses, and gamification for achieving universal accessibility in DT for architectural heritage (Cruz Franco, Rueda Márquez de la Plata & Gómez Bernal, 2022).

DT solutions also enable access to remote monitoring, vital for restricted locations or during crises like the COVID-19 pandemic (Singh et al., 2021) or becoming the platform for gathering citizen feedback to foster participation (White, Zink, Codecá & Clarke, 2021).

Inclusive DT solutions personalize services, such as human DTs that model behavior and characteristics through real-time sensor data (Asad et al., 2023), supporting data-driven ergonomics.

Therefore, the DT approach can foster social innovation in different fields. However, there is still limited literature that demonstrates how the DT approach can be a tool for inclusion and accessibility for the Public Sector.

3. Service Design in the Public Sector and Design for Inclusion

Thus, the literature review covers its second element, Service Design. Service designers are valued in the Public Sector thanks to their capacities to improve policy making (Mortati, Schmidt & Mullagh, 2022), to move towards necessary cultural and organizational changes, to train and build capacity among state employees, and to engage citizens through co-design sessions (Mager, 2016).

Moreover, for the successful integration of technologies, Service Design is becoming a necessity to create fruitful synergies between human operators and complex data structures (Colley & Häkkinen, 2018).

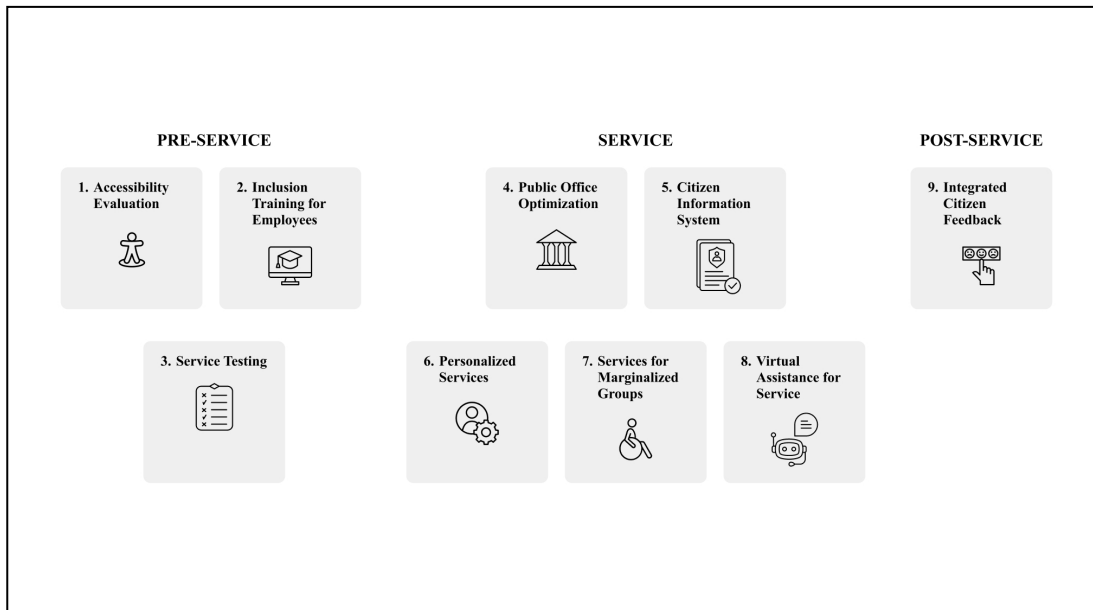
Design can promote inclusion and accessibility across digital technologies, as shown by numerous projects from product design to participatory design. Starting from Product Design, a significant example is the EASTIN Association, which provides expertise on assistive technology for people with disabilities, their families, and carers (Wouters, 2015). Another notable example comes from a Community-based Participatory design, called Commonfare.net, a platform enabling individuals in precarious conditions, such as poverty and unemployment, to share experiences and connect for mutual support (Lyle, Sciannamblo & Teli, 2018). Speaking of Design for social integration, a Digital Companion project uses AI-based profiling and chatbots to enhance public services for migrants and improve their quality of life through participatory co-creation approaches (Pollini & Caforio, 2021).

Despite these practices of using Service Design in the Public Sector and Design for inclusion, there is no Service Design literature yet on the integration of the DT approach for Social innovation in this area.

4. Framework of Digital Twin approach for Social Innovation in Public Offices

The integrative literature review finishes describing its two elements and results in tables 1, 2, and 3, which represent the new framework, building relationships between concepts of Digital twin and Service Design, that reveal 9 building blocks for Digital Twin function development within pre-service, service, and post-service (Stickdorn & Schneider, 2011). To focus the framework, the context was narrowed down from the Public Sector to public offices where the state employees communicate directly with the citizens, and thus, there is space for possible Social innovation intervention. The tables consist of five columns: the first is the possible DT function (what) in the public office [Fig. 1], the second and third are the (in)tangible interactions (how), the fourth is a benefit (why) associated with this DT function, the fifth is a possible role of Service designer and the last one is the similar case study. The description of the DT function is inspired by the Golden Circle model (Sinek, 2009).

The first table describes how DT functions within public pre-service can improve: accessibility evaluation through the office layout simulation for accessibility testing; inclusion training for employees to teach them handling diverse needs; service testing through the development of virtual experiment environments to service optimization. In this case, the Role of the Service designer is to develop scenarios and spaces to encourage engagement.

**Fig. 1**

DT functions within pre-service, service, and post-service in public office.

DT function (what)	Tangible Interactions (how)	Intangible Interactions (how)	Benefit (why)	Role of the Service Designer	Case study
1. Accessibility Evaluation	Simulate office layouts for accessibility testing	Collect and analyze citizen feedback to refine accessibility	Create an inclusive physical environment	Test and improve layouts, thanks to user feedback	Wouters, 2015; Hwang & Choi, 2023
2. Inclusion Training for Employees	Utilize XR simulations to train employees in handling diverse needs	Deliver AI-driven adaptive training programs	Improve inclusion of services	Design inclusive training scenarios	Barata & Kayser, 2024; Mager, 2016
3. Service Testing	Develop physical prototypes and virtual test environments	Aggregate real-time user interaction data to optimize services	Reduce risks and costs by initial validating, ensuring accessibility	Design participatory prototypes enabling citizen interaction	Barata & Kayser, 2024

Tab. 1 Pre-service in the public office improved by the DT approach and the role of the Service designer.

The second table describes how DT functions within public service can improve public office optimization that monitors physical flows of citizens/employees to manage queues; citizen information system that centralizes citizen data for easy access at service desks; personalized services that offer customized service recommendations at desks; services for marginalized groups that enable remote access for citizens with mobility challenges; virtual assistance that provides help at service desks. In this case, the Role of the Service designer is to develop data-driven user journeys and user-friendly systems.

DT function (what)	Tangible Interactions (how)	Intangible Interactions (how)	Benefit (why)	Role of the Service Designer	Case study
4. Public Office Optimization	Monitor the physical flow of citizens/employees to manage queues	Predict peak times and distribute staff	Reduce waiting times, predict problems, enhance citizen satisfaction	Design user journeys based on data	Barata & Kayser, 2024
5. Citizen Information System	Centralize citizen data for easy access at service desks	Track and update citizen profiles	Simplify interactions, improve transparency, and save time by consolidating information	Develop a centralized and user-friendly system	Eom, 2022; Asad et al., 2023
6. Personalized Services	Offer customized service recommendations at service desks	Analyze citizen interaction histories to tailor services	Increase satisfaction	Develop adaptive interfaces that personalize information	Pollini & Caforio, 2021
7. Services for Marginalized Groups	Enable remote access for citizens with mobility challenges	Provide adaptive digital interfaces for accessibility	Increase inclusivity for citizens unable to visit public offices	Design user-friendly remote service options	Singh et al., 2021; Tu et al., 2023; Cruz Franco, Rueda Márquez de la Plata & Gómez Bernal, 2022
8. Virtual Assistance for Service	Assist at service desks	Use a virtual assistant to guide citizens and provide solutions	Enhance transparency and empower citizens to navigate independently	Design accessible virtual assistants that provide support	Barata & Kayser, 2024; Pollini & Caforio, 2021

Tab. 2 Service in the public office improved by the DT approach and the role of the Service designer.

The third table describes how DT functions within public post-service can integrate citizen feedback to collect it through service desks. In this case, the Role of the Service designer is to develop accessible systems to ensure feedback informs decision-making.

DT function (what)	Tangible Interactions (how)	Intangible Interactions (how)	Benefit (why)	Role of the Service Designer	Case study
9. Integrated Citizen Feedback	Collect citizen feedback through service desks	Analyze feedback data to inform service adjustments and improvements	Promote transparency and foster citizen involvement and trust	Develop accessible systems to ensure feedback informs decision-making	Lyle, Sciannamblo & Teli, 2018; White, Zink, Codecá & Clarke, 2021

Tab. 3 Post-service in the public office improved by the DT approach and the role of the Service designer.

5. Discussions and Conclusion

The Framework of the Digital Twin Approach for Social Innovation in Public Offices proposes 9 building blocks for Digital Twin function development. Some of these blocks can be combined and integrated into existing Building DTs depending on the necessities.

The role of Service designers in fostering social innovation, inclusion, and accessibility through the DT approach is described for each DT function in the tables, and overall, their responsibilities can be summarized as follows:

- Engaging stakeholders and users, particularly marginalized groups: developing inclusive feedback loops using tangible and intangible interactions.
- Designing data-driven stakeholder journeys: plan their experience and develop inclusive tangible and intangible interfaces for DT systems.
- Prototyping and scenario development: designing them to test concepts and train employees.

The findings of this research help designers and public stakeholders understand the social, spatial, and relational impacts of DT systems, fostering deeper connections between citizens and public services. This research 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.

However, when implementing DT for social innovation, some ethical and technical challenges must be taken into account. Thus, future studies could be aimed at creating recommendations for policymakers to develop inclusive policies for public services, taking into account ethical and technical issues such as algorithmic bias and discrimination, privacy and surveillance issues, and large-scale data collection (Vesnic-Alujevic et al., 2019).

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