Article

JIM
ISSN: 2183-0606
(CC BY 4.0)
Vol. 12, 4 (2024)
p. 94-112
AM: Aug/2024
SM: Dec/2023

Impact in Urban Living Labs: Digital Twin Case of Bruges

Olivia Willems[1] and Dimitri Schuurman[2]

[1]imec, Miriam Makebaplein 1, 9000 Gent, Belgium | *olivia.willems@imec.be*
[2]imec-MICT-Ghent University, Miriam Makebaplein 1, 9000 Gent, Belgium | *dimitri.schuurman@imec.be*

Abstract

Urban Living Labs (ULLs) are increasingly used as an approach to facilitate sustainable solutions for urban challenges. Urban Digital Twins (UDTs) are regarded as technological enablers to assist in policy and data-driven decision making, capable of providing answers to urban challenges. In this paper we present a case study on an ULL project that resulted in the development of an UDT application in the Belgian city of Bruges. With this study, we looked for answers to two research questions: 1. How can an ULL approach be used to scope and develop an UDT application? 2. What is the actual impact of a fully functional UDT application for the city officials involved in the ULL process? The novelty of our research lies in the combination of ULLs and UDTs with the inclusion of a post hoc impact assessment. Main findings are that working with an ULL approach to scope and develop the Digital Twin use case yielded positive results in terms of desirability and feasibility of the project. However, in terms of viability of a complete Digital Twin solution for a single city, some issues were identified. The most added value was generated in terms of unintended learning regarding the followed ULL processes and innovation management approach which resulted in the adoption of new ways of collaboration and uncovered innovation opportunities for the city officials.

Keywords: urban living lab (ULL), urban digital twin (UDT), data-driven decision making, impact assessment, innovation management.

Cite paper as: Willems, O. , Schuurman, D., (2024). Impact in Urban Living Labs: Digital Twin Case of Bruges, *Journal of Innovation Management*, 12(4), 94-112.; DOI: https://doi.org/10.24840/2183-0606_012.004_0005

1 Introduction

Living Labs serve as open innovation ecosystems embedded within real-world contexts, facilitating user-driven innovation in tandem with the co-creation of services, products, and societal infrastructures (Leminen, 2013). They have emerged as pivotal instruments integrating user involvement throughout the research, development, and testing of innovations, with the aim of increasing European competitiveness and growth (Dutilleul, 2010). Organized as collaborative constellations, Living Labs promote engagement across diverse stakeholders, including businesses, academic entities, public-private partnerships, and communities (Schuurman, 2015). Drawing upon methodologies such as action research and user-centric design, Living Labs employ iterative processes encompassing requirement elicitation, co-design, prototyping, testing, monitoring, and commercialization (Eriksson et al., 2006). Therefore, we define Living Labs as proponents of

Editor's Note: This article was co-authored by one of the Guest Editors of this Special Issue and is included in the Special Issue because of its strong alignment to the issue's theme. To ensure impartiality, the editorial process was managed independently by the Editor-in-Chief.

Open and User Innovation, where a more long-term multi-stakeholder organization is established to orchestrate and execute multiple innovation projects including real-life testing and relying on user and stakeholder co-creation methodologies and tools (Schuurman, 2015).

In this context, Urban Living Labs (ULLs) emerged as a specific subtype aimed at solving urban challenges (Coyne, 2005; Peters, 2017; Steen & Van Bueren, 2017). ULLs are mostly supervised by the local government with a focus on social value creation (Baccarne et al., 2014) and a strong link with the urban environment (Kemp & Scholl, 2016). Despite their success, there are still a couple of challenges associated with ULLs, such as the sustainability and scalability of the approach (Hossain et al., 2019; Ersoy & Van Bueren, 2020) and the lack of robust impact assessments (Steen & Van Bueren, 2017; Paskaleva & Cooper, 2021; Ballon et al., 2018).

ULLs were originally regarded as an approach to the implementation of socio-technical innovations within an urban territory (Schliwa, 2013). Later literature extended this with ideas and policies (Votyenko et al., 2016) which increases the application domain of ULLs significantly, but at the same time decreases the conceptual focus. Therefore, we chose a case study in line with the original conceptualization of ULLs as urban experimentation with emerging technologies, closely linked to the domain of socio-technical innovation in an urban context.

Urban Digital Twins (UDT) are regarded as a promising avenue for urban data-driven innovation. However, the current literature stream tends to focus on technical aspects linked to setting-up UDTs with hardly any literature connecting ULLs and UDTs. Another novel element in our study is the measurement of impact. Governments are constantly on the lookout for ways to install governance with complementary tools into their strategic decision-making and communication process with the role of data becoming increasingly prominent. Whether digital twin technology can play a part in solving this quest, depends on the results and evaluation, thus impact, of the rather experimental nature of this method in the context of a municipality (Bulkeley et al., 2016; Kronsell & Mukhtar-Landgren, 2018).

Therefore, within this paper, based on a case study of an UDT project in the city of Bruges from 2019 to 2022, we tackle the following two research questions:

> $\mathcal{RQ}1$: To what extent is the proposed ULL approach effective in scoping and developing an UDT application?

> $\mathcal{RQ}2$: What is the actual impact of a functional UDT application for the city officials involved in the ULL process of scoping and developing?

Therefore, this study contributes to a gap in the literature by connecting an ULL approach with the scoping, development and impact assessment of an UDT, being among the first to systematically integrate the ULL methodology with the implementation of UDTs. This integration has the potential to offer a comprehensive method for cities to approach digital urban solutions, emphasizing iterative development and stakeholder engagement.

Furthermore, the inclusion of a post hoc impact assessment taking into account technical, economic, social as well as policy elements adds to the literature on impact assessment in ULL in particular and in Living Labs in general.

Consequently, this paper is structured as follows: in the following section, we describe the literature on Living Labs in general and ULLs in particular. Next, we discuss UDTs and their link with ULLs. Subsequently, the research methodology and case study are presented. These sections are followed by an elaboration on the findings and discussion, including the contribution to the current body of knowledge and the implications of our research. We conclude with a research

agenda proposing to explore the potential of UDTs and the role of ULL approaches in shaping and scoping use cases with the most valuable for public administrations and other involved parties of the quadruple helix.

2 Living Labs significance & Urban Living labs effectiveness

Since the early 2000s, Living Labs have received an increasing amount of attention, with the establishment of the European Network of Living Labs (ENoLL) in 2006 as the formal start of a global movement (Garcia et al., 2015). This movement focused mostly on largescale testing of ICT innovation, heavily embedded within the European regulatory and socio-economic context (Eriksson, Niitamo, and Kulkki, 2005). As the ENoLL network started to grow in waves with more and more certified members entering the network, the topics and application areas started to diversify, which could also be linked to European phenomena such as cooperative design and digital cities (Ballon and Schuurman, 2015). Next to the growing number of (certified) Living Labs, their geographic spread soon evolved from a European only network to a global network with currently 169 active members from 38 countries and 5 continents, with a total of almost 500 Living Labs having been certified since 2006 (Schuurman, 2023). This exponential growth in terms of practice has also been followed by a rich body of literature dealing with Living Labs and showing a wide variety of research avenues and perspectives.

One of the application domains that received a lot of research attention are so-called Urban Living Labs which focus on solving urban issues (Coyne, 2005; Peters 2017; Steen and van Bueren 2017). ULLs typically have a strong involvement of local authorities and focus mostly on social and /or societal value creation instead of business value (Baccarne et al., 2014), although private actors can play a substantial role in ULLs. Compared to Living Labs, ULLs also tend to be more focused on the short and medium term, implying a less sustainable organizational form with more emphasis on concrete projects and experiments than on a long-lasting organization (Schuurman, 2023). Kemp & Scholl (2016) further abstract five main characteristics: 1. hybrid organizational form at the border of local administration and society to gain the necessary space for experimentation, 2. the large link with the 'places' where these experiments take place and the resulting learnings that tend to get formalized at specific instances in the innovation process, 3. the multi-stakeholder setting, including the local administration, aimed at co-creation, 4. the experimental nature of ULLs, which is unusual for local administrations as this also allows failure as an outcome, and 5. approaching the (wicked) problems in a multi-disciplinary way.

Previous research has shown that by means of these elements, ULLs can bridge the gap between research and development on the one hand, and solution implementation on the other. This is achieved via the engagement of multiple stakeholder groups, leveraging upon distributed knowledge while facilitating cross-disciplinary collaborations (Voytenko, 2016; Steen & Van Bueren, 2017; Robaeyst et al., 2023). An Urban Living Lab is stated to have a distinct focus on knowledge and learning as a possible means by which such interventions can be successfully achieved (Bulkeley, 2022). Kemp & Scholl (2016) argue for more case studies to better grasp the innovative potential of ULLs, especially in the context of experimenting with new forms of urban planning.

However, next to these opportunities, there are also challenges associated with ULLs. Studies mention the transient nature of ULLs by running out of funding or (political) support, issues in terms of governance, lacking stakeholder involvement and issues in terms of sustainability and scalability (Hossain et al., 2019; Ersoy & Van Bueren, 2020). Additionally, robust impact assessments to discern ULL effectiveness is still under researched, which also underlines the

complexities inherent in evaluating and scaling ULL initiatives (Steen & Van Bueren, 2017; Paskaleva & Cooper, 2021; Ballon et al., 2018).

Regarding impact assessment, multiple options are suggested in the literature. Impact assessment can be classified as identifying the effects of certain actions or decisions, to evaluate certain changes caused by a distinct intervention (Ballon, Van Hoed and Schuurman, 2018). An ex-post impact assessment, where the evaluation aims to understand to what extent and how a policy intervention corrects the problem it was intended to address, is a plausible option (OECD, 2014). Another approach is the quasi-experiment, with the aim to evaluate interventions and demonstrate causality between an intervention and an outcome (H. White et al., n.d.). Further, an important distinction to make is expected versus actual impact. Impact could be simplified as a linear model between cause and effect, but in reality, this is less clear. Current theories of innovation stress the dependence on the surroundings of the process such as institutions, actors and broader social context (OECD, 2014). Finally, the type of impact investigated should be determined, as impact can occur in a lot of domains (e.g. economic, policy-related, environmental, societal...).

Within the context of Urban Living Labs, the public landscape can be characterized as ambiguous with several challenges such as navigating stakeholder relations, differing priorities and increased cutting of budgets. These are all factors that make organizational decision making more complex. To understand the values involved in strategic decision making in public administrations, the Viability Triad framework is proposed which includes the determinant factors *desirability*, *feasibility,* and *sustainability* (Bland & Osterwalder, 2019; Hunsaker & Thomas, 2017). Desirability links to the degree in which an innovation is able to solve the needs of certain key stakeholders. Feasibility relates to the degree to which the innovation is possible and mature in terms of technologies and solution components. Sustainability, which also can be translated as viability, is related to the business case or associated business model of the innovation. In an ideal scenario, resulting innovations from an ULL are desirable, feasible and viable, pointing at the intersection of these three elements.

3 Digital Twins in an Urban Living Lab context

The literature on Digital Twins has gained a lot of popularity since the first mention by NASA in 2010 in their technological roadmaps, formerly referring to a Virtual Digital Fleet Leader, and still has not passed its absolute peak, demonstrated by more than 7.000 hits with "Digital Twin" on Google Scholar, published only in the first quarter of 2023 (Shafto et al., 2012; Singh et al., 2021a). The majority of the publications deal with the technical and architectural aspects related to the UDT concept, defining the different elements of a 'real' Digital Twin or proposing future research avenues and potential benefits and caveats for cities and regions (Boje et al., 2020; Jones et al., 2020; Rasheed, San and Kvamsdal, 2020; Rudskoy, Ilin and Prokhorov, 2021; Singh et al., 2021; Topping et al., 2021; Khan et al., 2022; Wang et al., 2022). Quite some cases of UDTs are mentioned in literature, but their description and analysis remain illustrative for introducing some concepts, technical elements, or technological opportunities. However, none of these publications engage in an in-depth investigation of the actual impact of these UDTs on the individual level of the user. Hence the importance of this assessment, touching on both expected and actual impact of cross-domain and data-driven decision making of and by city officials.

When interest in Digital Twins started rising one decade ago, they were defined as a combination of a virtual and a physical product, together with their connections (Grieves, 2014). Some claim that before this definition was introduced, the concept already existed under different names. In

the academic literature there is consensus that today it can be categorized as an umbrella term with a broad range of interpretations with as central element a digital solution that could fit multiple business models (Harper et al., 2019; Vaska et al., 2021).

In this paper, we define a Digital Twin as a continuously updated digital representation of a physical object or process, combining real-time data and predictive models to provide insights into the perceived, actual or simulated state of the object or process (Rasheed et al., 2020; Singh et al., 2021). An UDT is a Digital Twin that represents the built environment of a neighborhood, city or region and its environmental impact with the primary goal of providing the tools and insights to support evidence-based decision making on operational and strategic level in an accountable way (Botín-Sanabria et al., 2021). According to domain experts, the critical challenges are related to interoperability and practical value, for example disparate semantic standards and a lack of beneficial business models (Lei et al., 2023).

The main added value of an UDT, specifically in a mobility context, is that it can grow with the city to reflect its vitality while allowing cross-domain decision making (Wang et al., 2022). The real balance to be found is between the city's constraints and the citizens' demands (Jiang et al., 2022). The results of former urban planning simulations have shown that there comes great power for cities by building in a feedback loop from citizens to policymakers to create a well-understood supporting base for final decisions. These interactions enable to prioritize current problems and generate suggestions for solutions (Marcucci et al., 2020; White et al., 2021).

In an urban environment the monitoring and control of air quality is an increasingly challenging demand (York Bigazzi and Rouleau, 2017; Topping et al., 2021). However, what remains contested in literature is to what degree urban traffic flow management has a critical effect on air quality on a city scale (Po et al., 2019).

Surprisingly, only few studies link ULLs with UDTs. Hristov et al. (2022) describe the synergy between digital twins in cities and ULLs. In joint efforts both concepts can deliver a complete showcase of technologies and services for delivering more liveable and sustainable cities. Enriching the city digital twin with data from the ULL uncovers an opportunity to create a more realistic replica of the city that better supports the decision making of public authorities. Marcucci et al. (2020) discuss on their part the relevance of Digital Twins for urban logistics Living Labs. However, instead of adopting a Living Lab approach for developing an UDT use case, they see them as a potential tool within ULLs to allow simulation before testing in real-life. In another study by Hämäläinen (2021), a case study of a local Digital Twin is presented which shows a lot of potential for coping with future city challenges. Nevertheless, barriers such as data quality, data sharing, and the investment of time and resources are identified. Regardless, this study lacks to make the link towards societal or policy impact.

Dembski et al. (2020) describe the most in-depth impact study of a Digital Twin prototype in Herrenberg, Germany. They conclude that up to this date, only few UDT projects have been singularly successful. Smart city projects demand two crucial competencies: an understanding of the impact of implementing digital technologies in the context of urban systems and integrating solutions that overcome departmental thinking. In this case study policy makers of several departments were included in making choices along the scoping process of the Digital Twin in their city. To understand the impact of the implementation of certain technologies, citizens were shown simulations so the data could support them in making decisions in the urban context. However, in terms of tangible policy impact, this study does not provide a lot of substantial information.

This overview illustrates that the field of Digital Twins in an Urban (Living Lab) context is still in development with only a few in-depth cases described in the literature with their actual impact and effectiveness still being more a promise than a thoroughly researched reality. Moreover,

most papers deal with technical aspects of UDTs and describe work-in-progress or pilot studies, with no longer-term implementations being investigated at this point. Therefore, within this paper we want to contribute to filling this gap with a case study that starts from the scoping, co-creation and co-design of an UDT use case in the city of Bruges and ends with an impact study of the actual usage of the UDT. Finally, we aim to add to the literature on UDTs by including broader perspectives, such as social, economic, and environmental factors, as this offers a more comprehensive view of UDTs and their role in shaping urban development beyond the purely technical and structural issues, which were dominant in previous studies.

4 Methodology

To answer our research questions, we adopted a qualitative research design focusing on an in-depth exploration of the case study, presented in the next section. This is complemented with post hoc in-depth interviews of key stakeholders to assess the perceived impact of the ULL approach and the resulting UDT use case. We chose this approach as qualitative research generates more holistic insights (Lester, Cho, and Lochmiller 2020), whereas a single case study offers the opportunity to have a more in-depth exploration of novel phenomena such as the combination of ULLs and UDTs taking into account the impact of societal, organizational and policy related perspectives of impact (Yin, 2009).

The case was selected as this is to our knowledge the first development of an UDT use case that took place outside the scope of an EU funded project, co-initiated by the city itself, with the involvement of all actors of the quadruple helix and with as outcome an application that was implemented and used by the city officials that were also part of the scoping, development and co-design of the application. This all aligns with the criteria for qualitative research in ULLs (Leminen, Nyström, and Westerlund 2020). This particular use case was also chosen because the author team was involved sideways (as one of the four collaborating parties) in the three year-long UDT project. This meant we had access to all internal documents and participating stakeholders which were used as material to reconstruct the case study.

For the impact study, we conducted in-depth interviews with all the city officials of the city of Bruges who were available and willing to be interviewed. As a criterion they had to be involved in the scoping, co-creation and co-design of the UDT use case and/or they had to have experience with using the UDT on-the-job. This resulted in a sample of ten city officials that were engaged for an in-depth interview. This group included a decision maker as well as city officials working in relevant divisions such as smart cities, (sustainable) mobility, public domain, data management, climate and environment. We excluded all city officials of Bruges who were not involved with the project anymore or did not have usage experience with the Digital Twin tool.

We assessed the impact of the Digital Twin application on six variables: the Digital Twin as a tool, the choice of the use case, the usability of the application, the use of the application as a supporting tool for decision making, the use of the application as a strategic tool, and the overall added value of the UDT and of the ULL approach that was used. We prepared semi-structured interviews, consisting of open-ended as well closed questions that included items that were scored on a scale from 0 to 10. The conversations lasted approximately 50 minutes and happened online via Teams from the 3rd till the 21st of February 2023. The topic guide consisted of future expectations and use, evaluation of the collaboration process and stakeholders as well as an evaluation of the application.

In terms of analysis, we used a deductive approach to assess the perceived impact of the UDT among the interviewees within the six surveyed criteria. To this end, all interviews were transcribed

and the answers to the open-ended questions were coded by the author team. The resulting codes were segmented and annotated based on emerging themes. For the closed questions means were calculated for the different statements. Our data analysis approach facilitated to gather both detailed, contextualized understanding of the qualitative data as well as additional insights from the scores provided by the interviewees on the six parameters to estimate relative satisfaction. The quality of the data might be obstructed because of the online context of the interviews, although there was an overall open atmosphere. Furthermore, the truthfulness of the answers could be questioned due to self-reporting. We mitigated this risk by taking the time to ask follow-up questions about uncertainties during the interviews.

5 Case study description

The city of Bruges, with over 118,000 inhabitants, is the capital of the province of West Flanders in the Flemish Region of Belgium. The historic center is registered as UNESCO Heritage Site for its medieval town. The cities' significance stems mainly from its traditional industry and services, schools at all levels and its seaport Zeebrugge. Above all, the city attracts travelers from across the globe. One of the core urban challenges of Bruges consists of the duality between the mobility priorities of its inhabitants versus those of the many tourists and commuters. With the development of their own Digital Twin, the city aims to visualize the influence of traffic flow adaptations in a specific area on the air quality model (Figure 1, Figure 2).

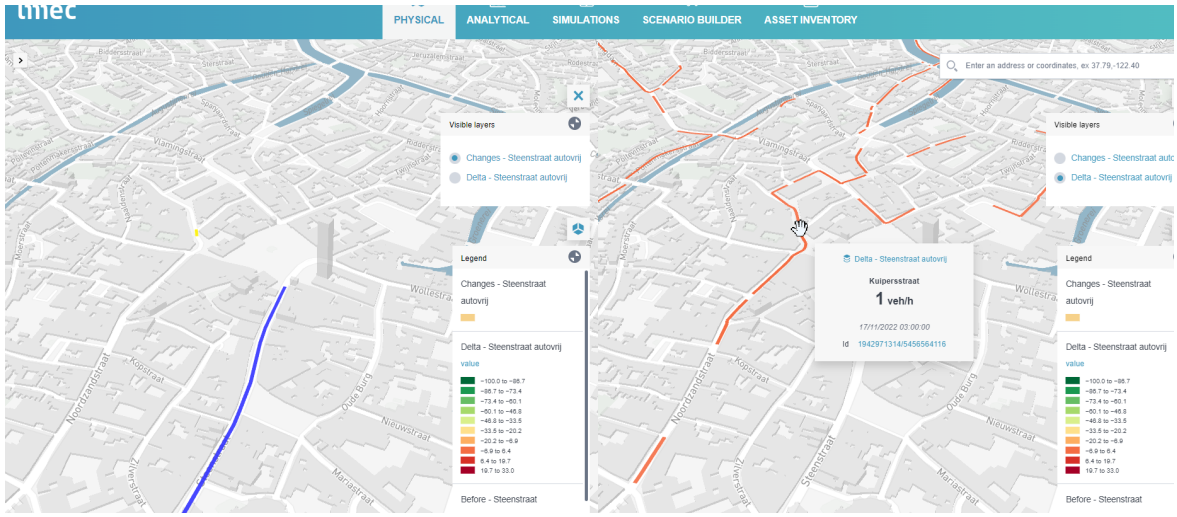

Figure 1. Digital Twin prototype of Bruges (traffic flows intervention).

To this end, they engaged research institute imec to help them in realizing this ambition[2]. The goal of the city officials of Bruges is to be able to simulate the impact of policy decisions, for example road closure, on air quality and traffic flows to provide an informed answer to policy requests and citizen complaints. This ambition and pilot project fitted within their climate plan to be realized by 2030. Over the course of three years, the scope and use cases of the Open Local Digital Twin of the city of Bruges were shaped in four iterative phases, following an ULL approach (see Schuurman et al., 2022): Exploring, Co-creating (via the Digital Twin sprint), Defining and Prototesting (Figure 3). This innovation management approach developed in the

2https://vito.be/en/news/prototype-digital-twin-city-bruges-offers-opportunities-all-flanders

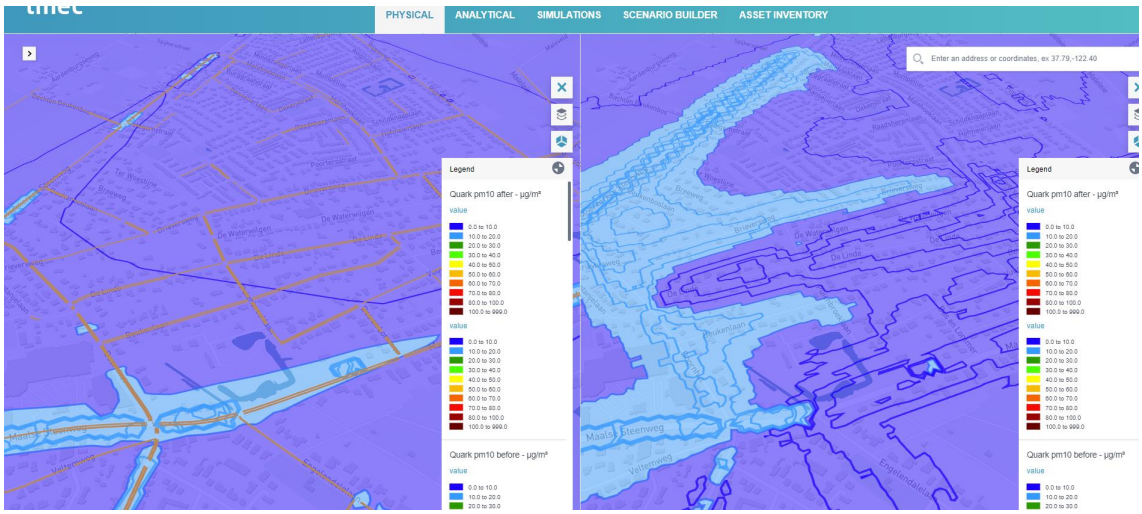

Figure 2. Digital Twin Prototype of Bruges (air quality after traffic flows intervention).

context of an ULL aims to tackle urban challenges in a tangible way, from scoping till project closing. This facilitates the identification of learnings and the implementation in future ways of working.

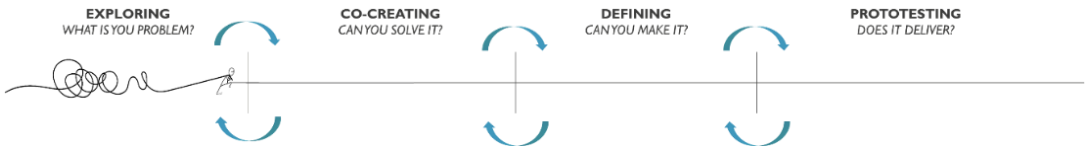

Figure 3. Overview of the ULL innovation management process.

The Exploring phase consists of defining and prioritizing the problem statements, filling out the Smart Data Use Case Canvas to define assumptions and create personas of the key stakeholders (Schuurman et al., 2022). The prioritized problem statement in Bruges was: "As an expert, I want to be able to simulate the impact of policy decisions (e.g. road closure) on air quality and traffic flows (in consideration of the climate plan 2020-2030) so that I can provide an informed answer to policy requests or citizen complaints". Finally, we described 6 personas of potential users including which tools they use, what needs they have and the problems they experience in their daily practice. During this phase, the decision makers from the city of Bruges together with the Digital Twin experts from imec collaborated to determine the scope and the size of the project. Based on the available data and infrastructure (feasibility) and the needs as articulated by the alderman of Bruges, the decision was made to focus on mobility and air quality.

The second phase of Co-creation consists of designing and testing of mock-ups in a sprint format. We started by translating use cases into high-level functionalities and design choices for the solution by using the predefined personas. We sequentially set up a user journey, user story mapping and the storyboard design. In the templates we mapped out the main user activities and tasks associated with the solution, key functionalities that should be embedded and user interactions which turned into design implications. The next step was selecting the needed data sources, component architecture and topology. Finally, we created and tested a clickable mock-up solution adopting a Wizard of Oz approach. To this end, it was decided to have a specific focus on

the street 'Vijversdreef', as there was a lot of civil protests regarding the possible implementation of new traffic signalization because of the cut-through traffic and the fact that there is a school in this street. This prototype represented the most important information and visualizations as defined in the co-creation phase. During this phase innovation managers, Digital Twin experts and prototypers from imec were involved to collaborate with a diverse group of people working at the city administration of Bruges in order to determine the use case and to ensure this was in line with concrete needs (desirability) and with the available data and infrastructure (feasibility).

Going into the third phase of 'Defining', we collected context information about the solution architecture and design of the system, containers, components, and code. If necessary, this was iterated upon during the project. We also refined the necessary data sources and requirements. This is a continuous process, as user feedback creates the need for new stories/requirements, adds new relevant sources, or demands making changes to existing requirements/data. During this phase, the research institute VITO was also involved because of their experience with air quality measurement and models, together with the software company CEGEKA because of their expertise on traffic modeling. This enabled to increase the feasibility of the UDT. Together with imec and the city of Bruges, they formed the consortium that in the following phase would effectively realize the UDT use case.

During the last phase of Prototesting, a composition of the words 'prototyping' and 'testing', we iteratively improved our working prototype until it delivered according to the needs of the city. We ensure this process by approaching it in an agile way of working. The three steps to follow are dashboard and data enrichment, forecasting and mapping traffic flows and lastly forecasting air quality and enclose cross-domain interaction. Through these steps we conducted user testing and user feedback reviews. In the Prototesting phase, next to the city officials, imec, VITO and CEGEKA, there were also citizens involved that lived in the 'Vijversdreef' and in neighboring streets that were to be impacted if the traffic signalization and situation would change. This helped to increase the desirability of the resulting UDT use case, although the main end-users would be the city officials.

6 Results

The analysis of the interviews reveals that the actual perceived value of the developed Open Digital Twin use case according to the individual users is quite high. This is shown by the overall score of the application and its value by the interviewees of 7 out of 10. The highest scoring evaluation criteria were *Digital Twin as a tool* and *Supporting tool for decision making*, which both have an average score of 7.2. One of the interviewees described his experience with the tool as follows: "*The Digital Twin is like a colleague who you work with side to side, proposing alternative solutions or policy decisions. The tool functions as a mirror, which creates opportunity to reflect on and optimize your own approach*". When asked about the tool as a strategic instrument, the average score was relatively the lowest with 6 out of 10. The majority of the interviewees explained this by stating they can see great potential in terms of developing an integral approach towards wicked problems. At the moment this is not possible as they do not have a fully functionable tool with a high degree of trustworthiness. However, their interest in future use cases is clearly demonstrated by the more than 20 suggestions from the interviewees, with spatial (green) planning being the one with highest priority.

In terms of the more qualitative feedback on the Digital Twin prototype, we deduct three main elements. Firstly, the proof-of-concept was and is still being used for actual operational decision making. This indicates that it solves an actual need. Second, the tool is said to help

in communication with and between citizens in relation to current urban problems and potential solutions. The objective aspect of the information and scenarios provided by the UDT facilitates and simplifies discussions across several communities: "*Policy makers can tell a coherent story with clear insights to neighborhoods, instead of having to mitigate arguments based on bias. It would be difficult to operate without the tool after the project closes*". Thirdly, there has been a positive evolution in their way of working and their prosperous outlook on data, agile project management and cross-domain collaboration. They see this as a direct effect of participating in the Digital Twin project and the followed methodology. As a tangible result of this, a data committee has been established within the public administration of Bruges.

We were able to identify common drivers and barriers of the interviewees to implement Digital Twin applications in the public administration. The drivers consist of objectifying cross-domain decision making and the forecasting feature also appeared to be crucial in the (near) future. Additionally, half of the interviewees also declared a specific benefit of the Digital Twin from the perspective of public relations: "*We are putting Bruges on the map. The project is opening doors because we are being innovative as a city*". The foremost reported barriers were the absence of a supra-local initiative to upscale the Digital Twin initiatives and the required efforts in terms of people and finances. These results clearly show the importance of involving all stakeholders, in this case the policy makers, citizens and industry partners, to purposefully scope and facilitate the integration of digital twins and ULLs towards a common ambition.

In the interviews we also assessed whether the proposed ULL approach is well suited for the development of urban innovations. We analyze the results based on the identified characteristics of Kemp & Scholl (2016):

"1. Hybrid organizational form at the border of local administration and society to gain the necessary space for experimentation."

This was clearly the case, as the local administration was involved in the various stages of scoping and developing the Digital Twin use case via the Living Lab sprint methodology, facilitated by the researchers and developers of imec. In the interviews, the respondents stated that this approach took them outside of their daily working routines which enabled them to approach the problem from a different perspective. Moreover, some interviewees even stated that the iterative approach and the innovation management methodology inspired them to approach their daily work in a different way, adopting a design-driven approach. This suggests that the hybrid organizational form at the border of the administration had a positive effect on their daily work.

"2. The large link with the 'places' where these experiments take place and the resulting learnings that tend to get formalized at specific instances in the innovation process."

The link with places became clear during the co-creation stage as a location needed to be chosen for the prototype. By choosing an area where the citizens were already arguing about the traffic situation, the Digital Twin use case had the potential to offer direct value. However, this choice in terms of specific place did make the 'air quality' aspect of the UDT use case less relevant as there were hardly any air quality issues in this area. The learnings linked to the 'place' mostly materialized during the Co-creation and the Prototesting phases.

"3. The multi-stakeholder setting, including the local administration, aimed at co-creation"

This was a reality throughout the whole process of scoping, developing, and testing of the UDT use case. The interviewees confirmed this intense co-creative process fostered an application that they were able to use and that was a fit with some of their needs. In the first two phases, the collaboration constituted of research institute imec and the public sector officials from Bruges. In the later stages, when the actual development took place, they were complemented by another research institute that contributed with technology (the air quality models) and topical expertise, and by a private company that contributed with practical development expertise and technology (the traffic model). In the final stage, some citizens were also involved to assess the desirability of the application. It was this collaboration that allowed to realize a working application. In this regard, a major finding was that the citizens became more open for different solutions when they interacted with the Digital Twin application as the visualization of the alternative solutions made them more aware of the implications.

"4. The experimental nature of ULLs, which is unusual for local administrations as this also allows failure as an outcome."

In the end, the outcome of the project was an UDT application that was effectively used by the city administration. However, it also became apparent that the usefulness of the application was promising yet limited in its current state. Therefore, this did not warrant large investments in terms of resources and learned that currently, there is no valid business case for building a Digital Twin for a specific use case in one city. However, this 'experimental' nature did clash somewhat with the expectations of the alderman of Bruges who had expected the application to be more mature and versatile at the end of the project.

"5. Approaching the (wicked) problems in a multi-disciplinary way"

The multi-disciplinary, iterative process was regarded by the interviewees as very enriching and can be interpreted as leading to the most successful outcome of the project, as the interviewees stated that they learned alternative ways of approaching problems within their daily working environment. The project also illustrated the need for multiple disciplines and skillsets from multiple actors of the Quadruple Helix to be involved to arrive at a working UDT application.

In this case study, we can state it was clearly confirmed that the approach of exploring and co-creating enables selecting valid problem statements that lead to a 'desirable' and 'feasible' use case. As a very important side effect that goes even beyond the scope of the UDT, the administration mentioned that they have integrated some best practices of the used methodology into their own processes: "*We are still using the design workshop and prince 2 format. We have learned a lot about long-term thinking and gained knowledge about standardizations and building blocks of the data platform*". The Prototesting phase has been validated to be critical to steer development in the appropriate direction, adapting towards needs of actual end-users. What was still lacking and should be further optimized, was the Defining stage. This could be due to the covid context which forced large parts of the process to be carried out online, but overall, the end-goal and the expectations should consistently be aligned between the stakeholders. This was already demonstrated by the three iterations that were done throughout the innovation management process during the phases of Defining and Prototesting in the shape of a repeated subsequently identification, visualization and simulation. Finally, the ultimate question of "what's next" from the perspective of the city remains. This is whether they will acquire the internal willingness to further implement the application and whether appropriate resources can be gathered ('viability').

7 Discussion

Regarding the antecedents and use cases for developing UDTs via an ULL approach, we learn that the urban context presents unique challenges. These include sensitivities such as keeping promises to citizens to deliver promised projects and the utmost importance of the justification of choices. Difficulties that arise are the relatively low data maturity of the administration and the position city officials find themselves in, balancing between the expectations of both governance and citizens. Another bottleneck in the city department of Bruges is the lack of dedicated internal resources in terms of people and money to spend on innovative projects instead of on their current daily tasks. Furthermore, the combination of topics of the use case has in hindsight appeared to be suboptimal. The effect of traffic flows on air quality is quite insignificant when operating on a microscale, for example whilst working with a sample that consists of a set of crossing streets.

While the Digital Twin is adapted to the needs of the users and aligns with the strategic goals of Bruges, the solution has not found a viable business case thus far. In terms of the technology, the administration is not quite ready for upscaling and in terms of resources, the project has consumed a lot of time and money from all actors involved.

The tool has already supported actual decision making and adds great value by offering an objective view on complex issues to facilitate discussions between stakeholders with varying priorities. The administration introduced a new data-driven, cross-domain way of working since the project. However, the full potential is not reached yet since the proof-of-concept in its current form cannot support more long-term, strategic decision making.

The city is facing a chicken and egg problem for the viability aspect regarding future investments of resources. While the different city departments should align more and truly work cross-domain to reap the full benefits of the Digital Twin, the staff is overburdened and budgets are already allocated to other tasks. Additionally, there is a high dependency on model providers that are in the present condition too local and specific. There is a need for upscaling to a real-life working model that can be self-maintaining.

Concerning the feasibility aspect, the data as well as the infrastructure are not ready for upscaling, since the availability and quality of suitable data to tackle core problems is the first step. Furthermore, the current prototype still requires too much domain and data knowledge to be able to correctly use the tool and interpret the outcomes. There is also a lack of trust in the accuracy of the predictions. More validation is essential to increase the future perception and adoption.

The public administration of Bruges still has some major steps to take before digitally transforming. We learned the most added value is the aid in strategic cross-domain decision making and predictive usage, rather than using the Digital Twin as an operational tool. Secondly, there is a need for shared, compatible infrastructure among cities and municipalities. Thirdly, an absolute precondition is the dedicated time investments of cooperating domain experts, instead of the fixed silo structured way of working as is. Lastly, there is a journey ahead for the administration to level up the maturity level of their data management as well as the digital skills and knowledge in-house.

Practical implications

The positive outcomes in terms of policy and data-driven decision-making underscore the value of investing in digital twin technologies. Policymakers might be more inclined to allocate resources to similar projects. The findings suggest a need for policies that support flexible, iterative innovation processes and encourage the adoption of new collaboration tools and techniques. The ULL approach involves stakeholder and community engagement. The case study might inspire other cities to involve residents and local businesses in a more proactive way in the development and

implementation of technological developments. Successful UDT projects can enhance public trust in urban planning initiatives by making processes more transparent and inclusive.

The identified issues with the viability of a complete UDT solution for a single city highlight the need for comprehensive cost-benefit analyses before large-scale investments. Our findings point to the need for a regional or even national basic technical infrastructure that can be leveraged by multiple cities and municipalities. Detected innovation opportunities can lead to new business ventures and economic activities related to urban technology and smart city solutions. The challenges faced in creating a complete UDT solution point to the need for scalable and interoperable technologies that can be adapted to different urban contexts. Overall, the UDT case of Bruges demonstrates the multifaceted impact of integrating digital technologies with urban planning and management through a collaborative, iterative ULL approach. The lessons learned can inform future projects, policies, and research approaches. By using the desirability, feasibility, andviability framework for our post hoc impact assessment, we provide a pragmatic approach that can be adopted by future researchers to evaluate urban innovation projects.

Theoretical implications

Within this paper, we have contributed to closing the gap between the literature on ULLs and UDTs by illustrating the applicability of the former approach to the development of the latter. The study is among the first to systematically integrate the ULL methodology with the implementation of UDTs. While ULLs have been used to address urban challenges and UDTs have been developed for data-driven decision making, their combined application provides a new framework for urban innovation. The study advances theoretical understanding by demonstrating how the ULL approach can enhance the scoping, development, and deployment of UDTs. This integration offers a comprehensive method for cities to approach digital urban solutions, emphasizing iterative development and stakeholder engagement. The novel inclusion of a post hoc impact assessment provides a methodological framework for future studies to evaluate the impact on several levels of urban innovation projects. By identifying and analyzing the challenges of an UDT's viability, the paper contributes to a more realistic, practical and holistic understanding of technology implementation in an urban environment, which is often missing in current studies. Finally, our research uncovers new collaboration methods and innovation opportunities for city officials which were not anticipated at the project's inception. These findings add to the literature on ULL outcomes by showing how they can lead to unexpected yet valuable outcomes in terms of governance.

8 Conclusion

In an industrial setting, Digital Twins have been around for a longer period with use cases such as predictive maintenance, but the multifaceted environment of cities and regions adds a lot more complexity to the mix. To effectively realize a Digital Twin use case in a city, an open innovation approach is necessary as this requires intense collaboration between multiple actors from the Quadruple Helix, including the city, research institutes, private companies and, in particular use cases, also citizens. In this study, we presented an ULL approach that matched all these requirements and led to the development and implementation of a Digital Twin use case. Although the presented case study of the Digital Twin project within the city of Bruges provides relevant and useful insights, it only showcases a fraction of the potential of an UDT. Onboarding more datasets, introducing machine learning and AI applications, and adding more parameters and a wider actionable area would allow to increase the strategic impact of the UDT. However, a

significant amount of effort and resources was already needed to develop this specific functional prototype, so careful consideration should be given to approaches that allow for scaling up and for reusing the created assets and infrastructure.

In terms of the ULL approach, aimed at balancing the three innovation elements Feasibility, Desirability and Viability, i.e. the viability triad (Hunsaker and Thomas, 2017; Bland and Osterwalder, 2019), of the UDT use case, the adopted methodology was highly valued by the participants. Careful scoping of the use cases based on actual needs and on available datasets is of utmost importance to be able to deliver a solution that is feasible and desirable. However, in terms of viability more emphasis should be put on upscaling and a common, shared infrastructure that most likely would go beyond the scope of a single city or municipality. A regional or even national initiative seems to be the possible answer here.

For the city of Bruges itself, three main areas of impact could be identified. First, a Digital Twin as a tool has the most impact in strategic decision making and as a communication tool amongst different stakeholders with sometimes conflicting interests (such as citizens from different neighborhoods). Second, the process of scoping and co-creating the Digital Twin use case had a profound impact on their own way of working. It installed a more open-minded culture and facilitated thinking beyond the traditional thematical silos, something which is also necessary to reap the full benefits of an UDT and cross-domain decision making. Third, although the actual use case and functional prototype are still actively used, the investment of time and human resources was substantial for the involved city officials. Therefore, further developments and additional use cases on a more strategic level are desired to warrant the investments already made.

9 Limitations

As this is a single case study, more studies are needed to investigate the effectiveness of an ULL approach in general and to see whether the positive effects, beyond the purely technical development of the UDT, also hold in other situations and for other use cases. Also, more studies looking into UDT implementations that are being used in the daily practice of city officials are needed to better grasp their impact and contributions. Another limitation is that within this study, we have limited ourselves to examine the impact of this case study from the perspective of the city officials. Future research is needed to better understand impact and implications for all involved stakeholders.

Acknowledgement

The authors received no financial support for the research, authorship, and/or publication of this article.

10 References

Abdeen, F.N. and Sepasgozar, S.M.E. (2022) "City Digital Twin Concepts: A Vision for Community Participation," in. MDPI AG, p. 19. Available at: https://doi.org/10.3390/environsciproc2021012019.

Baccarne, B., Mechant, P., & Schuurman, D. (2014). Empowered cities? An analysis of the structure and generated value of the smart city Ghent. Smart city: How to create public and economic value with high technology in urban space, 157-182.

Ballon, P., Van Hoed, M., & Schuurman, D. (2018). The effectiveness of involving users in digital innovation: Measuring the impact of living labs. *Telematics and Informatics*, *35*(5), 1201–1214. https://doi.org/10.1016/j.tele.2018.02.003

Bland, D. J., & Osterwalder, A. (2019). *Testing Business Ideas: A Field Guide for Rapid Experimentation*. John Wiley & Sons.

Boje, C. et al. (2020) "Towards a semantic Construction Digital Twin: Directions for future research," Automation in Construction. Elsevier B.V. Available at: https://doi.org/10.1016/j.autcon.2020.103179.

Botín-Sanabria, D. M., Lozoya-Reyes, J. G., Vargas-Maldonado, R. C., Rodríguez-Hernández, K. L., Ramírez-Mendoza, R. A., Ramírez-Moreno, M. A., De, J., & Lozoya-Santos, J. (2021). *Digital Twin for Urban Spaces: an Application*.

Bulkeley, H. (2022). Climate changed urban futures: environmental politics in the anthropocene city. In Trajectories in environmental politics (pp. 263-281). Routledge.

Bulkeley, H., Coenen, L., Frantzeskaki, N., Hartmann, C., Kronsell, A., Mai, L., Marvin, S., McCormick, K., van Steenbergen, F., & Voytenko Palgan, Y. (2016). Urban living labs: governing urban sustainability transitions. In *Current Opinion in Environmental Sustainability* (Vol. 22, pp. 13–17). Elsevier B.V. https://doi.org/10.1016/j.cosust.2017.02.003

Deckert, A. et al. (2020) "Chapter 9 - Digital tools in stakeholder participation for the German Energy Transition. Can digital tools improve participation and its outcome?," in The Role of Public Participation in Energy Transitions, pp. 161–177.

Dembski, F. et al. (2020) "Urban digital twins for smart cities and citizens: The case study of herrenberg, germany," *Sustainability (Switzerland), 12*(6). Available at: https://doi.org/10.3390/su12062307.

Eriksson, M., Niitamo, V. P., Kulkki, S., & Hribernik, K. A. (2006, June). Living labs as a multi-contextual R&D methodology. In 2006 IEEE International Technology Management Conference (ICE) (pp. 1-8). IEEE.

Ersoy, A., & Bueren, E. V. (2020). Challenges of urban living labs towards the future of local innovation. *Urban Planning, 5*(4), 89-100.

Garcia Robles, A., Hirvikoski, T., Schuurman, D., & Stokes, L. (2015). Introducing enoll and its living lab community. *European Network of Living Labs* (ENoLL).

Glaessgen, E.H. and Stargel, D.S. (2012) "The digital twin paradigm for future NASA and U.S. Air force vehicles," in Collection of Technical Papers - *AIAA/ASME/ASCE/AHS/ASC Structures, Structural Dynamics and Materials Conference*. Available at: https://doi.org/10.2514/6.2012-1818.

Granacher, J. et al. (2022) "Overcoming decision paralysis—A digital twin for decision making in energy system design," Applied Energy, 306. Available at: https://doi.org/10.1016/j.apenergy.2021.117954.

Grieves, M. (2014). *Digital Twin: Manufacturing Excellence through Virtual Factory Replication*. https://www.researchgate.net/publication/275211047

Hämäläinen, M. (2021). Urban development with dynamic digital twins in Helsinki city. *IET Smart Cities, 3*(4), 201-210.

Harper, K. E., Malakuti, S., Schlake, J., Ganz, C., & Petersen, H. (2019). *Digital Twin: An Enabler for New Business Models*. https://www.researchgate.net/publication/334884420

Hristov, P. O., Petrova-Antonova, D., Ilieva, S., & Rizov, R. (2022). Enabling City Digital Twins Through Urban Living Labs. *The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, 43*, 151-156.

Hunsaker, B. T., & Thomas, D. E. (2017). *The Viability Triad: Desirability, Feasibility, and Sustainability as the New Strategic Decision Imperative*. *5*(2), 2333–6056. https://doi.org/10.15640/jmpp.v5n2a1

Jiang, F., Ma, L., Broyd, T., Chen, W., & Luo, H. (2022). Digital twin enabled sustainable urban road planning. *Sustainable Cities and Society*, *78*. https://doi.org/10.1016/j.scs.2021.103645

Jones, D. et al. (2020) "Characterising the Digital Twin: A systematic literature review," CIRP Journal of Manufacturing Science and Technology, 29, pp. 36–52. Available at: https://doi.org/10.1016/j.cirpj.2020.02.002.

Julien, N. and Martin, E. (2021) "How to characterize a digital twin: A usage-driven classification," in IFAC-PapersOnLine. Elsevier B.V., pp. 894–899. Available at: https://doi.org/10.1016/j.ifacol.2021.08.106.

Kemp, R., & Scholl, C. (2016). City labs as vehicles for innovation in urban planning processes. *Urban Planning, 1*(4), 89-102.

Kronsell, A., & Mukhtar-Landgren, D. (2018). Experimental governance: the role of municipalities in urban living labs. *European Planning Studies*, *26*(5), 988–1007. https://doi.org/10.1080/09654313.2018.1435631

Lei, B., Janssen, P., Stoter, J., & Biljecki, F. (2023). Challenges of urban digital twins: A systematic review and a Delphi expert survey. In *Automation in Construction* (Vol. 147). Elsevier B.V. https://doi.org/10.1016/j.autcon.2022.104716

Leminen, S. (2013). Coordination and participation in living lab networks. *Technology Innovation Management Review, 3*(11).

Leminen, S., Nyström, A. G., & Westerlund, M. (2020). Change processes in open innovation networks–Exploring living labs. *Industrial Marketing Management, 91*, 701-718.

Lester, J. N., Cho, Y., & Lochmiller, C. R. (2020). Learning to do qualitative data analysis: A starting point. *Human resource development review, 19*(1), 94-106.

Marcucci, E., Gatta, V., Le Pira, M., Hansson, L., & Bråthen, S. (2020). Digital twins: A critical discussion on their potential for supporting policy-making and planning in urban logistics. *Sustainability (Switzerland)*, *12*(24), 1–15. https://doi.org/10.3390/su122410623

Michalik, D., Kohl, P. and Kummert, A. (2022) "Smart cities and innovations: Addressing user acceptance with virtual reality and Digital Twin City," IET Smart Cities, 4(4), pp. 292–307. Available at: https://doi.org/10.1049/smc2.12042.

OECD (2014) What is Impact Assessment? Retrieved at: https://www.oecd.org/sti/inno/What-is-impact-assessment-OECDImpact.pdf

Po, L. et al. (2019) TRAFAIR: Understanding Traffic Flow to Improve Air Quality; TRAFAIR: Understanding Traffic Flow to Improve Air Quality, 2019 IEEE International Smart Cities Conference (ISC2). Available at: https://www.eea.europa.eu/policy-documents/.

Rasheed, A., San, O., & Kvamsdal, T. (2020). Digital twin: Values, challenges and enablers from a modeling perspective. *IEEE Access*, *8*, 21980–22012. https://doi.org/10.1109/ACCESS.2020.2970143

Robaeyst, B., Van Hansewyck, N., Baccarne, B., & Schuurman, D. (2023). A Qualitative Analysis of The Value Creation of Urban Living Labs. *International Journal of Innovation Management, 27*(05), 2340007.

Rudskoy, A., Ilin, I. and Prokhorov, A. (2021) "Digital Twins in the Intelligent Transport Systems," in Transportation Research Procedia. Elsevier B.V., pp. 927–935. Available at: https://doi.org/10.1016/j.trpro.2021.02.152.

Schliwa, G. (2013). Exploring living labs through transition management-challenges and opportunities for sustainable urban transitions. IIIEE Master thesis.

Schuurman, D. (2015). Bridging the gap between Open and User Innovation?: exploring the value of Living Labs as a means to structure user contribution and manage distributed innovation (Doctoral dissertation, Ghent University).

Schuurman, D. (2023). Living Labs: voorbij de hype. *Holland Management Review, 40*(206), 62-72.

Schuurman, D., Wuyts, G., & De Meester, T. (2022). *Living Labs for Scoping Digital Twins: Introducing Imec's Innovation Management Approach*, 258–271. https://openlivinglabdays.com/wp-content/uploads/2022/12/OLLD-2022-Proceedings.pdf

Shafto, M. et al. (2012) Modeling, SiMulation, inforMation technology & ProceSSing roadMaP Technology Area 11.

Singh, M., Fuenmayor, E., Hinchy, E. P., Qiao, Y., Murray, N., & Devine, D. (2021). Digital twin: Origin to future. In *Applied System Innovation* (Vol. 4, Issue 2). MDPI AG. https://doi.org/10.3390/asi4020036

Steen, K., & Van Bueren, E. (2017). The defining characteristics of urban living labs. *Technology innovation management review, 7*(7).

Topping, D. et al. (2021) "Digital Twins of Urban Air Quality: Opportunities and Challenges," *Frontiers in Sustainable Cities, 3*. Available at: https://doi.org/10.3389/frsc.2021.786563.

Vaska, S., Massaro, M., Bagarotto, E. M., & Dal Mas, F. (2021). The Digital Transformation of Business Model Innovation: A Structured Literature Review. In *Frontiers in Psychology* (Vol. 11). Frontiers Media S.A. https://doi.org/10.3389/fpsyg.2020.539363

Voytenko, Y., McCormick, K., Evans, J., & Schliwa, G. (2016). Urban living labs for sustainability and low carbon cities in Europe: Towards a research agenda. *Journal of cleaner production, 123*, 45-54.

Wang, Z., Gupta, R., Han, K., Wang, H., Ganlath, A., Ammar, N., & Tiwari, P. (2022). Mobility Digital Twin: Concept, Architecture, Case Study, and Future Challenges. *IEEE Internet of Things Journal*, *9*(18), 17452–17467. https://doi.org/10.1109/JIOT.2022.3156028

White, G., Zink, A., Codecá, L., & Clarke, S. (2021). A digital twin smart city for citizen feedback. *Cities*, *110*. https://doi.org/10.1016/j.cities.2020.103064

White, H., Sinha, S., & Flanagan, A. (n.d.). *A review of the state of impact evaluation*. http://www1.worldbank.org/prem/poverty/ie/db/evaluationdb.htm

York Bigazzi, A. and Rouleau, M. (2017) "Can traffic management strategies improve urban air quality? A review of the evidence," *Journal of Transport and Health.* Elsevier Ltd, pp. 111–124. Available at: https://doi.org/10.1016/j.jth.2017.08.001.

Yun, Y. and Lee, M. (2019) "Smart City 4.0 from the perspective of open innovation," *Journal of Open Innovation: Technology, Market, and Complexity, 5*(4). Available at: https://doi.org/10.3390/joitmc5040092.

Biographies

Olivia Willems. Olivia Willems holds the position of Innovation Analyst at imec, where she has been working since 2022. She is responsible for driving innovation across several key domains, including mobility, automotive, education, learning, and smart cities. Her work involves spearheading initiatives related to new and emerging technologies, with a strong focus on stakeholder management, business case development, and governance reporting. Olivia brings a wealth of expertise in user research, futures & foresight, workshop facilitation, and voice of the customer analysis. She is also deeply involved in academic research on impact methodology within the context of Living Labs, contributing to the development of innovative approaches in this field. Olivia holds a Master's of Science degree in Communication Sciences, with a specialization in New Media & Society. She leverages her background to bridge the gap between technology and societal needs, ensuring impactful and inclusive solutions.

ORCID: https://orcid.org/0000-0001-5350-9159

CRediT Statement: Data curation; Formal analysis; Investigation; Software; Visualization; Writing - original draft

Dimitri Schuurman. Dimitri holds the position of university business development manager at research group imec-MICT-Ghent University where he is responsible for research on inclusive design, impact via Living Labs and design for futures, all in the context of new and emerging technologies. He is also a visiting professor strategic design and innovation management at Ghent University in the industrial design studies and partly works for the European Network of Living Labs as senior research strategist. Since 2015 Dimitri holds a PhD on innovation management in Living Labs from Ghent University (UGent) and the Free University of Brussels (VUB in which he developed a three-layered model that is now widely used in Living Lab research as well as practice. He published more than 200 academic papers, acted as guest editor for multiple journals and for over ten years leads a special interest group on Living Labs in the International Society for Professional Innovation Management (ISPIM). Finally, since recently, Dimitri is also active as an independent consultant in the domains of open innovation, user innovation and strategic innovation management.

ORCID: https://orcid.org/0000-0003-4006-0596

CRediT Statement: Conceptualization; Funding acquisition; Methodology; Project administration; Resources; Supervision; Validation; Writing - review & editing