Meri Jalonen (ed.)

Smart Cities in Smart Regions

Conference Proceedings

LAB University of Applied Sciences

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Foreword

The Third Smart Cities in Smart Regions conference has been a joint effort of LAB University of Applied Sciences and Avans University of Applied Sciences. The idea of organising the next conference in collaboration emerged during the second SCSR conference in 2018 in Lahti. The plan was to convene in 2020 in Breda, the Netherlands, but the covid-19 pandemic intervened. Finally, after several postponements, the conference took place in April 2022.

Within the almost four years that passed between the two conferences, both our everyday lives and the world around us have changed abruptly. The pandemic had a direct impact on the organisation of the conference, since changing infection rates and health security policies needed to be considered. While the war in Ukraine, which began after the call for papers had ended, was not directly reflected in the conference presentations, it made some of the conference topics, such as security, ever more acute.

Meanwhile, the original conference topics have not lost their significance. The need to tackle climate change and other ecological crises remains urgent; the development of smart and resilient cities and regions calls for collaboration among various stakeholders. Both the keynote speeches and conference presentations at the Smart Cities in Smart Regions conference discussed novel approaches, technologies and methods to the development of sustainable products, services and infrastructures. This conference proceedings offers insights into these issues through an interesting set of academic papers and case studies.

We would like to thank all the authors and presenters for their contributions to the conference. We also want to thank the members of the Scientific Board and the reviewers of abstracts and papers for taking care of the quality of the conference programme and the proceedings. Finally, we thank the entire conference team at Avans University of Applied Sciences and LAB University of Applied Sciences for making the conference a fruitful gathering.

Lahti and Breda, 6th of December, 2022

Meri Jalonen
Chair of Scientific Board

Ben Kokkeler
Vice-Chair of Scientific Board

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Introduction

The Third Smart Cities in Smart Regions conference called for papers under three themes:

Active citizenship & smart city infrastructure, Design, technology & digitalization, Circular Economy and Entrepreneurship. The suggested papers went through a peer-review evaluation process by a panel of reviewers and the scientific board of the conference.

The proceedings includes two kinds of papers, Academic papers and Best practices and case studies. ***Academic Papers*** are either empirical studies using consistent methods and presenting results based on the systematic analysis of empirical data, or reviews that provide significant insight into a specific topic and a critical analysis of the related literature. ***Best Practices and Case Studies*** are well-documented studies of an implemented technological innovation or development project, which provide an analysis of a specific problem, description of the implemented solution and evaluation of outcomes and impact.

To highlight links between the topics of the published papers, the conference proceedings is structured under three thematic sections:

- **Citizens and other stakeholders as co-creators of Smart Cities and Smart Regions** presents papers that analyse experiences and participation possibilities of citizens and other societal stakeholders in smart city initiatives.

- **Designing and testing technological solutions for Smart Cities** presents papers that explore and evaluate the potential of various technological solutions to provide data and services for smart city development.

- **Practices and policies for promoting the Circular Economy** presents papers that discuss exemplary activities that have the potential to advance circular economy at the regional level.

The scientific board of the conference hopes that the readers will enjoy this combination of papers that provides examples of interesting developments of Smart Cities and Smart Regions.

The Involvement of Citizens and Other Stakeholders in the Development of Smart Cities and Smart Regions

Academic Paper

Value-ing the Smart City: A Study of the Values of Different Stakeholders regarding Living Lab Scheveningen

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Abstract

Smart city technologies can improve effectiveness and efficiency of urban processes and systems, but they do not automatically make a city an attractive and meaningful place for residents. To fully realize the potential of a smart city, design must not only take technological aspects into account, but also emotional, intellectual, and symbolic aspects of interactions with technology. Values are increasingly used as a perspective to ensure a meaningful experience. However, deciding what values to take into account in designing technology is not straightforward. In this paper we present an exploratory study to identify different types of values regarding Living Lab Scheveningen, a smart city project in The Hague, The Netherlands. Values of residents, visitors and entrepreneurs in the district, as well as policy makers and civil servants were collected and categorized in different categories. The results show that a lot of values are considered important across different stakeholder groups, but that there exist different interpretations and prioritizations of these values among different stakeholders. Accounting for these values in the development of Living Lab Scheveningen could create a place that is more meaningful for the citizens who visit, or work or live in it.

Keywords
*Smart city, living lab, values,
value-sensitive design, human-centered*

1. Introduction

Smart cities are often described in terms of utilitarian functions such as energy savings, efficient waste disposal or water management. However, although Internet of Things (IoT) applications in smart cities improve effectiveness and efficiency of urban processes and systems, they do not automatically make a city more meaningful to live in (Hollands, 2008). The utilitarian aspect of a smart city is only one aspect in designing a meaningful experience. Attention to the emotional, intellectual, and symbolic aspects of interactions with technology is also essential to user experience (McCarthy & Wright, 2007; Hassenzahl, 2010; Norman, 2004). To fully realize the potential of a smart city, design must not only take technological aspects into account, but also institutional and human aspects (Nam & Pardo, 2011; Cocchia, 2014). The experience of citizens is thus indispensable in a city that is not only efficient, but also livable, attractive, and meaningful for residents (Van Waart & Mulder, 2014).

In recent years there has been a growing focus on ethics in relation to technology. In this regard, values regularly form a steppingstone to identify ethical and social consequences of technology and to bring about responsible design of technology (Harbers, 2018; Friedman & Hendry, 2019; Kool et al, 2017; Spiekermann, 2015). Also, when it comes to smart city design, values are increasingly used as a perspective to ensure a meaningful experience (Harbers et al., 2015; Van Waart et al., 2016; Steinert & Roeser, 2020). However, deciding what values to take into account in designing technology is not straightforward. Literature on values distinguishes between different value systems (Bos-de Vos, 2020). For instance, a distinction is made between personal and public values. Personal (human) values largely determine the way individuals experience the world around them, e.g., freedom, safety and friendship (Rokeach, 1973; Schwartz, 1992). Public values that are safeguarded by democratic governments such as health, social equity and sustainability are important for a society as a whole. It is often assumed that public values are an aggregation of values of individuals, but this is only partly true (Jørgensen & Rutgers, 2015).

This paper describes an exploratory study to identify different types of values regarding a smart city project in The Netherlands. To identify values in this study we followed a value sensitive design approach, in which values are defined as that which a person or group of people consider important in life (Friedman & Hendry, 2019). To classify values, we used the framework provided by Umbrello and Van de Poel (2020) because it explicitly focuses on AI applications. The framework distinguishes three types of values. The first type consists of ***values to be promoted by design,*** for example, a surveillance camera that contributes to the value of security. The second type refers to ***values to be respected by design***. An example is the value of privacy when in the context of a surveillance camera. The purpose of the surveillance camera is not to promote privacy, but when the technology is deployed, the value of privacy must be respected. The third type of values are ***context-specific values.*** These are values that are not specifically related to a technology but important in the context in which the technology is applied.

The context of our study is Living Lab Scheveningen. Scheveningen is a district of The Hague, a city with a population of over 500.000 people in the Province of South-Holland in The Netherlands. Scheveningen is located at the North Sea and has a pier, a boulevard, a beach that is popular for water sports such as surfing, and a harbor that is used for both fishing and tourism (see Figure 1). The district also contains areas with cafés and restaurants, shopping areas and residential areas. ***Living Lab Scheveningen*** is an initiative of the Municipality of The Hague to address metropolitan issues with smart solutions based on the latest technologies (https://smartcity.denhaag.nl). The Hague Municipality and the Province of South-Holland are determined to actively involve citizens in the 'smart city' developments within Living Lab Scheveningen.

Figure 1: Robot prototype and smart lamp posts on the boulevard of Scheveningen.

The purpose of this research is threefold. First, it aims to provide more insight into the values of various stakeholders that influence the perception of Living Lab Scheveningen. Here, the term ‘stakeholders’ refers to residents, visitors, and entrepreneurs in the district, as well as policy makers and civil servants who are responsible for Living Lab Scheveningen. The results do not give an exhaustive picture of all the values that are relevant in this context but give a good impression of the most important values and how they are experienced by different stakeholders. Second, this research aims to convey the perception of citizens to civil servants. Therefore, research methods were used that based on an active approach involving both citizens and civil servants. Third, this study provides insight in the use of Umbrello and Van de Poel’s framework by applying it to a new case.

The remainder of this paper is organized as follows. Section 2 describes the process of collecting and analyzing values, section 3 presents the results, and section 4 consists of a discussion and conclusion.

2. Data collection and value analysis

For the elicitation of values among different stakeholders, we used four types of methods to collect data on values regarding Living Lab Scheveningen: conversations in the field, stakeholder interviews, an experience probe, and desk research. To expose a wider range of values we reached out to respondents from different stakeholder groups through the network of contacts of civil servants of the municipality. To convey the perception of citizens to the municipal and provincial civil servants, they were involved as much as possible in the execution of the research activities.

Conversations in the field. During the opening week of Living Lab Scheveningen, short conversations were held with civil servants (who were given a tour) and citizens (passers-by) on the boulevard of Scheveningen during three afternoons in September 2020. Participants were asked to what extent they were positive or negative about possible scenarios of data sharing and why, for example, images from cameras on lampposts being shared with the police. The conversations were held by the authors and civil servants from the Province of South Holland. The participants' responses were noted on sticky notes on the spot and stuck on a board. In total, data from 40 people were collected.

Interviews with stakeholders. Four individual interviews were conducted with representatives of the main stakeholder groups: a resident of Scheveningen, a regular visitor to the area, an entrepreneur from the neighborhood and a civil servant working in Scheveningen. Respondents were asked about their relationship to the area and their opinion regarding the technologies in the use cases. Through a laddering interview technique, they were asked about the underlying values. In this way, opinions, experiences and related values towards Living Lab Scheveningen and the neighborhood were collected from the different stakeholders.

Experience probe. Five residents and regular visitors to Scheveningen participated in an experience probing activity during one week in December 2020. Each day the participants received a text message with an emotion (unsafety, happiness, irritation, proud and worry) and they were instructed to go to a place in their neighborhood that evoked a memory or association linked to that emotion. They were asked to take a picture of that place and send it to one of the researchers, accompanied with a short explanation about the exact location, the emotion that was involved and what the place meant to them. The purpose of this activity was to gain more insight into the emotional experience of citizens of Scheveningen district. The experience activity was devised, inspired by the research method of the cultural probe

(Gaver et al., 1999). Figure 2 shows what kinds of results were obtained through this activity.

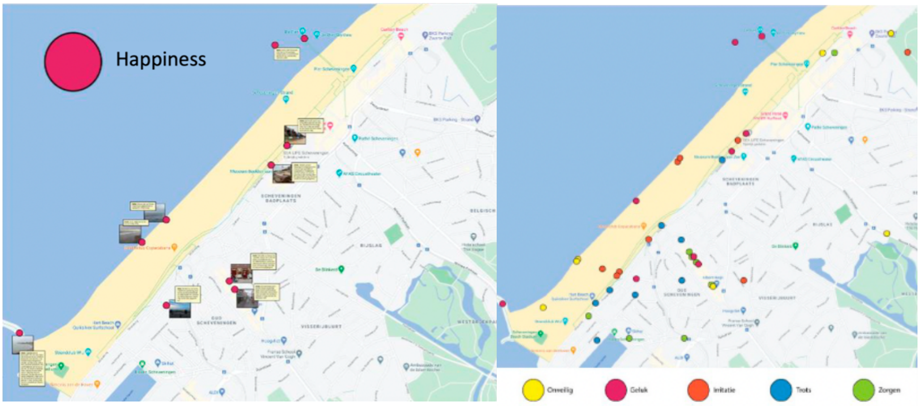

Figure 2. Results of the experience probe on a map of Scheveningen: places associated with happiness (left) and places associated with all five emotions (right).

Desk research. Several sources of information about Living Lab Scheveningen were collected and studied: a policy document describing the Living Lab, promotional information on the website of the Municipality of The Hague (www.denhaag.nl), and a formal letter with the rationale of the Living Lab Scheveningen to the Chair of the Governance Committee by the Alderman of Education, Economics and International of the Municipality of The Hague (Bruines, 2019).

After collecting the data, a values analysis was conducted in three steps. In step one, all collected text data (i.e., sticky notes collected on the boulevard, interviews, explanations accompanying the pictures from the experience probe, and the (policy) documents) were used to identify quotes that related to a value. Most of the selected quotes explicitly refer to a value, and some quotes do not literally refer to a value but have a clear link to it according to the authors of the paper. The quotes contain both positive and negative references to values. For example, a positive reference to the value security is ‘that will make the boulevard safer’ and a negative reference to the value trust is ‘that is not good for the trust people have in the government’. This step resulted in a collection of text fragments that refer to a value, keeping track of which research activity (boulevard, interviews, experiential probe and desk research) and from which stakeholder (resident, visitor, entrepreneur and official/government) the value was derived.

In step two of the value analysis, all text fragments were grouped by the authors. Text fragments about strongly resembling values were combined in one category, for example text fragments about the values ‘insight’ and ‘transparency’ and text fragments about the values ‘social contact’ and ‘sociability’. Then, by intersubjective agreement, the authors selected ten important values that emerged in the research results. They selected values that were mentioned frequently and that were brought up by multiple respondents and addressed in at least two of the research activities. The result of this step is a collection of ten values with accompanying text fragments.

In step three, the ten values were classified in the three categories of Umbrello and Van de Poel’s framework: values to be promoted by design, values to be respected by design and context-specific values.

3. Values at stake in Living Lab Scheveningen

Table 1 shows the results of the value analysis described in the previous section. The findings for each of the value types will be discussed.

The ***values to be promoted by design*** (i.e., safety, sustainability and engagement) were often mentioned by citizens and civil servants. Notably, in the formal letter describing the rational of Living Lab Scheveningen to the alderman all these values were explicitly mentioned. These values then might be seen as what value literature mentions as public values. The text fragments accompanying these three values show that both citizens and officials are largely positive about the pursuit of these values by Living Lab Scheveningen activities. However, citizens and officials sometimes give different interpretations to the values; for example, when thinking of safety, citizens think primarily of the sea and traffic, while safety on the boulevard is emphasized more in the government perspective.

Of the ***values to be respected by design***, the value ‘functionality’ emerged mainly from the government perspective and the value ‘responsibility’ was particularly evident in expressions from citizens. The other values, ‘transparency’, ‘privacy’ and ‘trust’, were frequently mentioned by both citizens and civil servants. The text fragments show a diversity in the perception of different values, where there are differences between different stakeholder groups and differences within one stakeholder group. For example, some of the residents and visitors saw the technology in Living Lab Scheveningen as a threat to their privacy, while others did not.

The ***context-specific values*** found in this study (i.e., social contact and pleasure) were widely present in the text fragments from citizens, and not so much, if at all, in the text fragments from the government perspective. For the purposes of this study, providing insight into values that influence the experience of Living Lab Scheveningen and conveying the experience of citizens to officials, this category of values is of particular interest. Whereas the first two categories of values are well represented in the governmental perspective, this is not the case for the for context-specific values, which are more personal rather than public. While it may not be the government's explicit task to promote values such as pleasure and social contact among citizens, it might be important for governments to take this type of values into account in the development smart city technologies. Considering these values provides an opportunity to increase citizen participation in designing smart city technologies and increase their meaningfulness for citizens.

Category	Values
Values to be promoted by design	Safety Sustainability Engagement
Values to be respected by design	Efficiency Privacy Transparency Trust Responsibility
Context-specific values	Social contact Fun

Table 1. Overview of different values elicited from stakeholder groups in Living Lab Scheveningen classified according to the framework of Umbrello and Van de Poel (2020).

4. Discussion

This study was considerably impacted by the corona pandemic, as the research activities with stakeholders took place between September 2020 and January 2021. Due of the pandemic it was not allowed to organize physical gatherings with groups of citizens and civil servants, it was more difficult to approach citizens (physically) to ask if they would join in research activities, and many people had to deal with deviant home situations such as homeschooling that made participation in research activities difficult. We had to change our plans several times and come up with alternatives for some of the research activities we had originally planned. That said, we managed to collect and analyze data that were relevant for the purpose of this study. In the introduction we outlined three research goals, each of which we will discuss.

The first goal was to obtain insight into the values at stake for different stakeholders with respect to Living Lab Scheveningen. This study yielded a list of ten values, divided into three categories as shown in Table 1. First, we would like to stress that the identification and categorization of values was a subjective task, performed by the two authors. We had a high intersubjective agreement, but the results present our perspective. When other people would have done the analysis, this may have led to other outcomes. An extra complication here is that different values mean different things to different people. However, unraveling the diversity of meanings that different stakeholders assign to each value was beyond the scope of this project. Despite the subjectivity, we believe that there are still some interesting points of discussion.

We expect that the values that were found were influenced by the corona pandemic. The current research has provided richly illustrated information about values that influence the perception of Living Lab Scheveningen, but these values fall primarily into the categories of 'values to be promoted by design' and 'values to be respected by design'. We believe that research activities we had to cancel or adapt due to corona measures, particularly the activities in which citizens and civil servants would meet in groups, would have provided more insight into context-specific values. We expect that the two values found in this category are only the tip of the iceberg of a large diversity of values that influence the perception of citizens of Living Lab Scheveningen.

The values that were found in the first two categories (values to be promoted by design and values to be respected by design, respectively) were considered important by both citizens, and civil servants and other government officials. Interestingly, we found a lot of agreement among the stakeholders on which values should be promoted by Living Lab Scheveningen, while there were many differences in views on how to take the values in the second category into account. These results seem indicate that there is more agreement in what should be achieved with technology, in other words, for what goals technology should be used, than in how technology should be used, in other words, in what way impacts of technology should be taken into account and what preconditions the technology should meet.

The second research goal of this study was to convey the perception of citizens to civil servants. This goal was most strongly affected by the corona pandemic. Conveying citizens' perceptions to officials would occur primarily through immersive research activities involving interaction between citizens and officials. However, the only research activity where there was direct contact between citizens and officials was the collection of responses on the boulevard. The participating civil servants indicated that this activity provided a lot of insight into citizens' perceptions in a short period of time. This supports our belief that research activities in which civil servants are engaged can help achieving the research goal to convey the perception of citizens to civil servants.

The third research goal was to obtain insight in the use of Umbrello and Van de Poel's value framework. We found the framework highly intuitive when using it to classify the different values, and at no point differed in view on how to classify a value. The classification also helped to interpret the results. For example, it helped noticing that the government perspective was highly underrepresented in the category of context specific values.

5. Conclusion

In this paper we presented an exploratory study to identify different types of values of different stakeholders regarding Living Lab Scheveningen. The results show that a lot of values are considered important across different stakeholder groups, but that there exist different interpretations and prioritizations of these values among different stakeholders. Future activities that bring citizens and civil servants together can make (other) context-specific values of citizens transparent and understandable for civil servants. Moreover, an overview of values at stake can form the basis of a co-creation sessions in which different stakeholders work together to design the smart city. Such value-based activities can increase the engagement of citizens in the development of Living Lab Scheveningen, and develop it in such a way that it is more meaningful for the citizens who visit the place and who live and work there.

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Best practices and Case Studies

Smart Is as Smart Does: Low Power Personal Area Networks (LPPAN) for Orchestrated Co-creation of Smart Cities

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- Panu Jalas
  Silicon Labs

Abstract

The state-of-the-art wireless Low Power Personal Area Network (LPPAN) technologies, such as Bluetooth mesh, Thread, Zigbee Wi-Fi, Wi-Sun and others, make it possible for individual organizations or even citizens to setup affordable ad hoc smart city infrastructures. These networks can be created without commercial network operators and without investment in expensive infrastructure, such as land cables or cellular base stations. LPPAN networks enable new types of smart city services by co-creation, which can be orchestrated by municipalities, smart technology providers, individual businesses or even individuals through active citizenship. In this article we discuss the opportunities and challenges of LPPAN technologies for smart city solutions based on active citizenship. We will also focus on the motivational factors that either encourage or discourage individuals or businesses to actively contribute to the co-creation of smart city solutions. We additionally discuss how the solutions could be orchestrated by or together with municipal and regional organizations. Propositions will be introduced on the above-mentioned issues.

Key words
smart infrastructure, services, active citizenship, co-creation orchestration

1. Introduction

A Smart City can be defined as an urban environment where 'investments in human and social capital and traditional (transport) and modern (ICT) communication infrastructure fuel sustainable economic growth and a high quality of life, with a wise management of natural resources, through participatory governance' (Caragliu et al. 2011, 70). Smart Cities clearly provide a testbed for technological innovation in urban environments, where technology ideally provides opportunities for innovative solutions to smaller and bigger challenges related to citizens' everyday life. These smart environments do not 'happen' by themselves but require multi-stakeholder orchestration: motivating collaboration between different stakeholders and individuals through active citizenship, with or without Public-Private Partnerships (PPP). According to Hirvikoski et al. (2020), the challenges we face in a globalized world are of a kind that require a new way of thinking and acting: they require openness, inclusiveness and heightened collaboration that are pre-requisites to enhancing the involvement of multiple stakeholders in co-creation and joint value creation. Interestingly, the measures required seem to call for both formal and informal interventions in the ecosystems being developed (Hirvikoski & Saastamoinen 2020).

The focus of the present paper involves exploring the means for active citizenship, which is not a given, but requires complex processes and careful planning. Why would an individual take the trouble of engaging in urban development co-creation activities, when e. g. the entertainment domain calls her to stay at home and watch a film or read a book or go outside for a jog. The objective of the present paper is to discuss current opportunities and challenges related to modern wireless ICT infrastructures when they are used to bring about sustainable economic growth and higher quality of life. We will explore this through the case of LPPAN technologies for Smart City or Region solutions. In doing so, we will also discuss motivational factors of active citizenship related co-creation activities by multiple stakeholders and touching also on the challenges such citizen engagement can cause e. g. in data privacy. The research question of the present paper is as follows: What opportunities do LPPAN technologies provide for Smart City infrastructure and service development, and what challenges must be considered in such co-creation activity? The results may provide novel viewpoints for multi-stakeholder collaboration in the hope of contributing to the present practices of co-creation orchestration in Smart Cities.

2. Literature Review

How to bring about active citizenship and what does it entail? Promoting active citizenship is a strategy of the European Commission in order to increase social cohesion and democracy across Europe (Mascherini et al. 2009). A survey carried out in 2009 by the EU Joint Research Council showed differences between the EU countries, age groups and gender regarding active citizenship related activities (ibid.). Active citizenship involves the following domains and activities (see Figure 1 below):

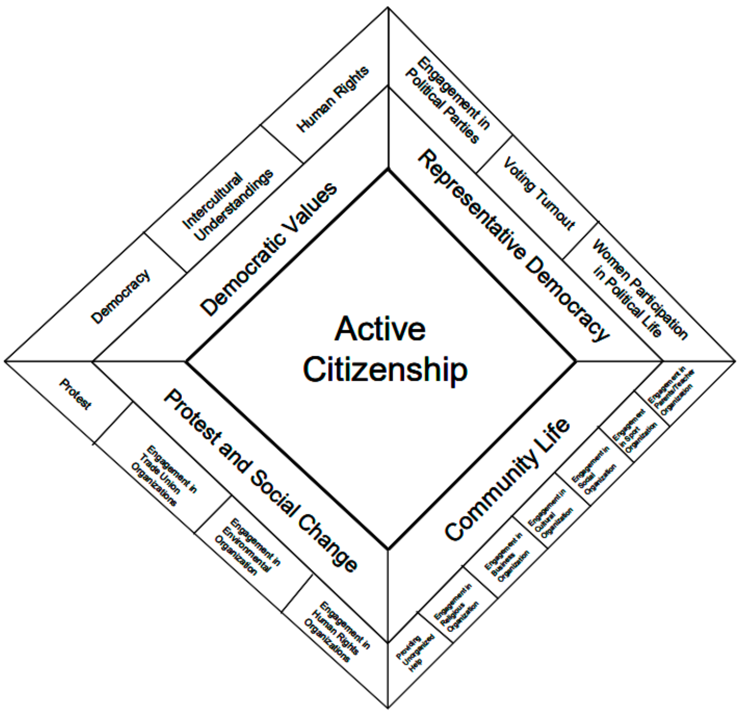

Figure 1: Components of Active Citizenship (Manscherini et al. 2009)

For the purpose of the present study, we are mainly interested in the domains of Community Life and Social Change depicted in Figure 1. In Europe, scholars detected that more than ten years ago, people of middle-age groups were more socially and community-wise active than younger generations. Also in the Nordic countries, women were more active than men, which was vice versa in southern European countries (Manscherini et al. 2009).

Today, participation in service development is commonplace across the services sector, at least at the rhetorical level. Scholars claim, however, that too often participation and citizenship fail to materialise through practice in everyday life (Percy-Smith 2015): being a citizen and acting as one - where the rights to citizenship are being actively fulfilled - are quite distinct. Engaging in society-related joint activities in order to promote the common good is not evident. Nearly half of the population in the European Union do not make it to the election polls at the EU level (Wikipedia 2021); however, they may be more interested in engaging in local Smart City development in order to promote common good regionally. The motivation may be higher for regional engagement, as a socially interdependent model of citizenship in which participation is based on mutual and reciprocal relationships (Fitzgerald et al. 2010) may come into play.

2.1. Smart City citizenship: definition and implications for the future

Four components of techno-centric Industry 4.0 have been identified: 1. cyber-physical systems (CPS), which bring the physical and the virtual world together; 2. internet of things (IoT), adding new technologies, such as sensors or RFID tags, to everyday objects making them connected to internet through a Personal Area Network (PAN); 3. internet of services (IoS), and 4. smart factories (see Hermann et al. 2015, Hofmann and Rüsch 2017, Ashton 2009 in Calzada 2021). The aim is to move towards more human-centric Industry 5.0 and thus Society 5.0, which is Smart and deepens technological integration in improving the quality of life, social responsibility and sustainability (Önday 2019).

According to some scholars (see Calzada 2021 for more information), people can be described as Smart Citizens if they are guided by a particular set of set values and behaviours. Firstly, such citizens are interested in the environments where they live and work and are willing to take responsibility for maintaining the places that they appreciate; secondly, they are more interested in being able to access places, services, etc. and involving themselves, rather than ownership and power (cf. sharing economies, Selloni 2017); thirdly, smartness involves sharing know-how and helping others who may be less technologically oriented (Calzada 2021).

2.2. Smart City developments: motivation and self-determination theories

Citizens of Smart Cities are often seen as passive data providers: they are encouraged to provide feedback and perform certain roles in providing solutions to practical issues (Cardullo & Kitchin 2018). Urban Living Lab interventions, however, see participants as playing a more active role as co-producers - developing critical analyses and practical suggestions in order to tackle urgent problems, such as pollution, mobility and health (ibid; see also Calzada 2021).

Active citizenship is easier said than done. While Smart City services are being developed through technical smartness of infrastructure, according to scholars (Oliveira and Santos 2018), Smart Cities too often fail to exploit the most important dimension in urban development: people. They argue further that the city challenges are effectively addressed at the level of the neighborhood; this should be remembered when developing Smart City services via citizen-centric, participatory approach (ibid.).

When planning citizen engagement, scholars claim that play is an important principle for understanding new manifestations of civic engagement (Glas et al. 2019). Generally, creativity, experimentation, open-endedness and playful citizenship should be examined more closely (ibid.). In enhancing civic engagement, it is important to go beyond disciplinary boundaries in order to really understand citizenship; fields such as media studies, science and technology studies, design studies, game studies, play studies, communication studies, and urban studies should be combined (ibid).

2.3. Co-creation orchestration in Smart Cities needs to be Penta-Helix-based

Cities and regions have been collaborating in their development practices in non-smart and smart ways for decades (see e. g. Raunio et al. 2018; Baldersheim 2016). Scholars suggest that Smart Cities should become ***experimental cities*** where the citizens are at the centre of the smartness transformation (Satyam and Calzada 2017). The following Table 1 shows the difference of conceptual approach in Smart Cities versus experimental cities with citizens having a clearly more active role in the experimental city.

Concept	In Smart Cities	In Experimental Cities
Smart citizen	User or data provider	Decision-maker
Politics of data	Big data	Data sovereignty
Notion of city	As market	As platform
Data ownership	Owned by firms	Publicly scrutinized
Stakeholder helix	Triple or quadruple	Penta helix
Business models	Public-Private Partnership	Urban co-operative platforms
Scalability	Based on urban solutionism	Unpacking urban problems
Algorithmic coding, disruption	IoT sensor networks	Citizen-sensing
Governence	E-government systems	Living Labs
Causability	Linear, normative	Complex, adaptive systems

Table 1: Moving from smartness to experimentation (adapted from Satyam and Calzada 2017)

Scholars (see Calzada 2021) view the need to move towards experimentation from Smartness, which is often seen as merely technocratic; it will be important for citizens to become aware of the fact that they can manage their future in urban environments by being conscious of their rights to the city, on the one hand, and duties in urban development, on the other. This will require reassessing issues such as ownership of data, which can result in alternative modes of funding and business models e. g. in the form of co-operative platforms and community-based data (see Blok et al. 2017). Especially Urban Living Lab experiments highlight interdependencies among stakeholders; the Penta-Helix multi-stakeholder framework is presented as including a fifth helix: social entrepreneurs, activists and brokers, in addition to public-private-academia-civic society collaboration (triple and quadruple helix) (Mazzucato 2015).

3. Analysis of case study of LPPAN as an enabling technology

The present paper aims to provide new insight on urban development in the context of Smart Cities and related infrastructure in general and LPPAN technologies in particular. Such technology can enable new types of Smart City services, bring about sustainable economic growth and generally improve citizens' quality of life. The development of these new types of services can be orchestrated by municipalities, smart tech providers, businesses or even individuals through active citizenship. Hence, we are also interested in considering motivational factors. In order to answer the research question: 'What opportunities do LPPAN technologies provide for Smart City infrastructure and service development, and what challenges must be considered in such co-creation activity?', we have provided a brief and focused literature review. The aim is to use the case of LPPAN networks through observation which is bounded by subjectivity. The research approach is abductive, which involves starting with an observation or set of observations and seeking the simplest and most likely conclusion from the observations (see Dubois and Gadde 2002).

In order to answer the research question, we will start by reviewing technical opportunities. In practice, a Smart City is powered by smart connections for various items such as street lighting, smart buildings, distributed energy resources, smart transportation and electric vehicles, sensors and data analytics nodes. The modern PAN technologies make it possible to create very affordably large ***ad hoc*** networks, without cellular base stations or land cables, which require a centralized network operator. The nodes of the PAN network form a mesh, which can be connected to internet via a gateway or even a smart phone application providing an IP address. The maintenance and data security can be controlled by the local owner of the network or bought as a cloud-based service over the internet. The PAN mesh can be extended to create smart city functions through active citizenship in local communities, small businesses or even by individuals without heavy investments or subscription fees to Wide Area Networks (WAN), such as cellular networks, or wired cable network operators.

Table 2: Network solutions for the backbone of a smart city

Property	LPPAN	WAN (cellular)	Cable
Capacity	◆ several MB ◆ sensory data ◆ metering (electrical, water, gas) ◆ Control of devices, switches	◆ several GB ◆ audio ◆ video	◆ Limitless (optical cable) ◆ audio ◆ video
Cost	◆ very low investment ◆ no subscription	◆ high investment ◆ subscription based	◆ Very high investment ◆ subscription based
Power	◆ low power ◆ battery operated nodes	◆ low to medium power ◆ cell phones ◆ gateways	◆ medium power
Coverage	◆ wireless local mesh of nodes, max 2 km between network nodes	◆ ubiquitous wireless availability	◆ dependent on cable installations
Mainte-nance	◆ Maintenance by network owner	◆ Maintenance and installations by network operator company	◆ Maintenance and installations by network operator company

For example, Chaudhari, Zennaro and Borkar (2020) discuss in detail the design considerations and benefits of wireless IoT technologies. They point out that IoT applications require energy-efficient and low complexity nodes for a variety of uses that are to be deployed on scalable network. In contrast, cellular networks such as 2G, 3G, 4G and 5G are designed primarily for voice, data, and video communication, and not for IoT applications, where the data rate is relatively small, but energy efficiency and battery operation are often required.

Currently, there are several technology standards such as Bluetooth, IEEE 802.11 or IEEE 802.15.4 which form the basis for a very wide range of software protocols, used in local and personal networks. The brand names for these protocols include e. g. Bluetooth Mesh, Zigbee, Wi-Fi, Z-Wave, Wi-Sun, Wirepas and others. However, from application development point of view, the fragmentation of the technologies to so many different protocols is a problem. The many application interfaces are usually not interoperable, which means that the software solutions, connecting appliances and sensors using one protocol, are not applicable for a network using a different protocol. In order to circumvent the problem, Apple, Google, Facebook and Samsung launched ***Matter initiative*** (CSA 2020), which is meant to be a unified application layer for the network development, so that despite the fact that the underlying software, the physical layer of the network technology connecting to the sensors and appliances, was different (for example, Bluetooth and Zigbee), the developers could still create solutions with a uniform Matter interface standard. Although ***Matter initiative*** is currently driven by smart home applications, it might be deployed in smart city applications in the future, lowering the threshold for easy and nimble creation of interoperable LPPAN networks with little resources.

Most of the LPPAN technologies use either the 2.4 GHz band, which is an internationally available license free frequency band for DIY applications or a license free sub-GHz frequency, which is typically a band between 400-900 Mhz, depending on country specific regulations. For smart city applications, the sub-GHz frequencies provide typically a longer range, up to 2 km between network nodes, whereas 2.4 GHz based technologies can provide a better connectivity to local smart building or smart home appliances, especially to Bluetooth mesh/Wi-Fi based building specific networks.

Table 3 lists some practical examples where LPPAN technologies have already been used to create Smart City solutions.

Table 3: Examples of motivational factors for LPPAN based Smart City solutions

Motivation	Use Case
Cost Saving	◆ Street lighting ◆ Smart grid control and monitoring
Ease-of-Use	◆ Wireless metering ◆ sensors to cloud Street lighting
Improved safety	◆ Smoke, gas and leak detectors ◆ Motion detection ◆ Smart lighting ◆ Smart doorlocks
New services	◆ Smart censoring ◆ Parking ◆ Waste Management

As a consequence, the low-cost implementability of Smart City innovation opens the possibility for the local community or even an individual citizen to function actively at the centre of the whole innovation management process. The questions arise:

- How to motivate individuals, communities, etc. to take an active role in smart city infrastructure opportunities?
- How could municipal governance and state governance play a part in orchestrating motivation?

Figure 2 below summarises the possibilities for active citizenship in Smart Cities.

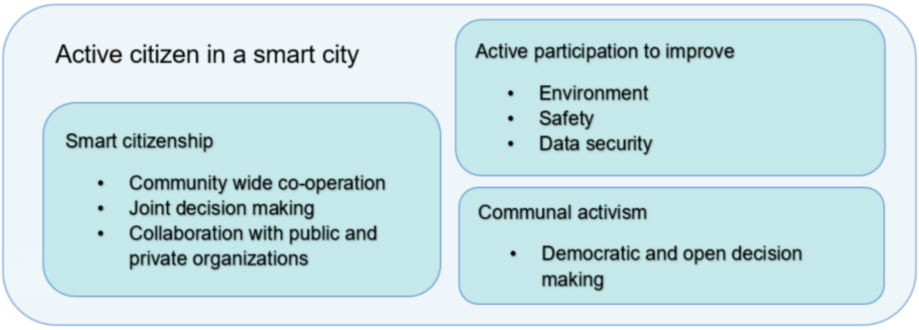

Figure 2: Active citizenship in a Smart City

Being active should be voluntary, yet, financially lucrative to citizens. Similarly to cities benchmarking each other, communities and neighbourhoods could take part in playful competitions for improving community life and promoting social change.

4. Results and conclusions: propositions on co-creating via LPPAN enabled service solutions

As a synthesis of the theoretical and practical considerations via the case of LPPAN enabling infrastructure and services in a Smart City via active and smart citizenship, we are putting forth the following propositions regarding the challenges and opportunities detected in Smart City co-creation orchestration:

Proposition 1: Active citizenship materialises the most likely locally, at the level of the neighborhood which can be an opportunity for a LPPAN based infrastructure to enhance Community Life.

Proposition 2: Smart citizens take responsibility for the quality of life in their ***experimental communities***. Locally mastered LPPAN infrastructure can provide a useful opportunity for co-creation if motivational factors support such developments: e. g. ***ease of use*** of smart metering; cost saving via smart grid solutions, ***improved safety*** via smart lighting and sensor-to-cloud solutions, new services such as smart environmental sensoring, waste management and parking.

Proposition 3: Playfulness should be integrated in active citizenship engagement: co-creating novel environments and related applications should be engaging, even entertaining. Neighbourhoods could engage in playful competitiveness in other European experimental cities through engaging in visits; cities and businesses could sponsor such activity.

Proposition 4: Co-creation should be linked to self-determination in order to attract citizens' engagement, on the one hand – engaging is voluntary; on the other hand, Smart citizens could share know-how of successful LPPAN with communities elsewhere.

Proposition 5: Penta-Helix-based collaboration focuses on experimentation, integrating novel actors: social entrepreneurs, activists and brokers – in order to generate high tech solution with a high social value (see Mazzucato 2015; Calzada 2021). Also, universities of the arts and universities of applied sciences can join forces, and such associations can suggest new organizational structures to encourage creativity.

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Designing and Testing Technological Solutions for Smart Cities

Academic Paper

State-of-the-Art of the Urban Digital Twin Ecosystem in the Netherlands

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Abstract

The Netherlands has a long tradition in monitoring and assessing its natural and built environment through the use of diverse and reliable databases. Several Dutch governmental bodies have been utilizing urban digital twins (UDT) as a decision support tool that consolidates and analyzes existing spatial and non-spatial datasets. Among other reasons, the Omgevingswet, the new Dutch environmental code expected to take effect in 2022, has motivated government bodies and companies to advance with their digital twin initiatives. According to Geonovum (2021), a digital twin is a dynamic system where objects and processes from the environment are established by data, models and visualizations, supporting simulations and evidence-based decision-making.

In this context, this paper aims to assess the existing UDT initiatives in the Netherlands undertaken by both the public and the private sector in order to draw insights about the challenges, opportunities and the use of digital twins within the country. The research relied on publicly available information on the Internet and interviews with stakeholders in the UDT ecosystem. The method for this research follows four steps: 1) finding UDT initiatives via searching organizational websites; 2) developing a UDT assessment template based on academic and practical literature; 3) identifying UDT project leaders and conducting interviews for data collection; 4) consolidating the collected qualitative data from the interviews and drawing conclusions.

From May to September 2021, 10 interviews were undertaken with key project leaders in their respective organizations. Among 40% of interviewees played mainly a technical role in the project, while 60% had a mainly managerial position. All of the interviewees had sufficient knowledge of both managerial and technical aspects of the projects they were involved in. The main findings are that most UDTs are already operational, but still being improved and extended in terms of data layers and features. The typical budget over 2 years ranged from €400.000 to €600.000 to reach the current development stage and most UDTs have funding secured for the next few years. It was concluded that the Netherlands has a vibrant ecosystem of UDT with government, suppliers and universities engaged in the development of new solutions, but still some challenges remain such as the difficulty of including citizens in the design and operation phases and a lack of an impact assessment framework.

Keywords
digital twins, smart cities,
city management, urban innovation

1. Introduction

The Netherlands have a long tradition in assessing and monitoring changes in the built environment through the implementation of reliable spatial and non-spatial databases. Founded in 1832, the Dutch cadaster organization, Kadaster, began with the measurement of land for tax purposes. After 1885, a nationwide triangulation network was implemented as an effort to match the assessments of different cities and over the years, it grew to the important entity that it is today (Kadaster, 2022a). Having an autonomous national entity dedicated to the cadaster was an important step for territorial management in a relatively small country administratively divided into provinces and municipalities of different kinds.

The Kadaster holds publicly accessible datasets on multiple topics. Some of these datasets consolidate information about assets nationwide (i.e. roads, bridges, buildings) in base registers, known as ***basisregistraties***, containing spatial data such as all addresses and buildings, roads, railways, cadastral parcels and topographic files (Kadaster, 2022b). For better policy and management, some governmental entities and partner companies are currently developing the ***Basisregistratie Ondergrond*** (BRO) (Kadaster, 2022c), a central registry with public data on the Dutch subsurface.

Taking advantage of the possible integration of plenty of existing databases about various aspects of the territory, the ***Omgevingswet***, the new Dutch environmental code, will join 26 regulations into one code in order to simplify the permitting processes. This new regulatory framework requires multiple datasets to be accessible for different stakeholders, supporting their decision making processes by enabling them to perform technical analyses and providing quick insights about new proposed buildings, companies and activities (IBR, 2022). The core instruments of this new legal framework offer plenty of opportunities for the use of digital twins.

In this context, the governmental organization responsible for geographic studies and standards, Geonovum (2021), has proposed a National Digital Twin for the Built Environment (National ***Digitale Tweeling van de Fysieke Leefomgeving*** - DTFL), that could be used as public set of instruments by governments, citizens, companies and knowledge institutions, exploring societal challenges in the physical living environment and designing and developing solution scenarios.

For Batty (2018), a digital twin is "a mirror image of a physical process that is articulated alongside the process in question, usually matching exactly the operation of the physical process which takes place in real time". This paper aims to assess Dutch digital twins developed at a urban-scale, so called Urban Digital Twins – UDT, or those with a strong spatial component, such as important transportation infrastructure or vast territories (i.e. the whole land or a province) undertaken by both the public and the private sector in order to draw insights about the challenges, opportunities and the use of digital twins in the Netherlands.

2. Methods

A method was developed to frame the main technical and administrative aspects of the projects in this field of urban digital twinning. Aiming to better understand the Dutch digital twin landscape, it follows four steps: 1) finding digital twin initiatives by searching organizational websites; 2) developing a digital twin assessment template based on academic and practical literature; 3) identifying digital twin project leaders and conducting interviews for data collection; 4) consolidating the collected qualitative data from the interviews and drawing conclusions.

An assessment framework was designed in order to document the different digital twin projects in the Netherlands considering comparable aspects. The approach consists of sections of questions regarding: a) respondents' background; b) the use of city/region data; c) considered administrative conditions, d) organizations and their role in the digital twin ecosystem; e) quadruple helix engagement; f) technologies adopted; g) project development process; h) final remarks.

Since there is no complete and publicly accessible documentation on all the digital twin initiatives available, the projects were assessed by interviews lasting around one and a half hour with key professionals involved in each digital twin initiatives. The majority of questions posed to stakeholders were open-ended in order to enable a deeper qualitative understanding of the different projects.

Table 1: Conducted interviews.

Name of the Project	Type of Initiative	Respondents	Affiliation	Date of Interview
Brainport Smart District (BSD)	Private	Tom van Tilburg (Senior Researcher) and Janne Verstappen (Business Consultant)	Geodan	07/05/2021
Lekdijk Digital Twin	Public	Peter de Graaf (Business Consultant)	Geodan	18/05/2021
3D Amsterdam	Public	Wietse Balster (Product Owner)	City of Amsterdam	08/06/2021
Rotterdam 3D	Public	Roland van der Heijden (Program Manager)	City of Rotterdam	17/06/2021
3D Utrecht	Public	Frans de Waal (Information Architect)	City of Utrecht	18/06/2021
Groningen 3D Digital City	Public	Leontien Spoelstra (Consultant in Geo-Information)	City of Groningen	25/06/2021
Digitwin	Private	Jeroen Steenbakkers (Company Owner)	Argaleo	05/07/2021
Tygron Platform	Private	Florian Witsenburg (CEO)	Tygron	14/07/2021
Future Insight Digital Twins	Private	Rick Makkinga (Project Leader)	Future Insight	14/07/2021
Eindhoven Stadsmodel	Public	Michiel Oomen (Digital Innovation Program)	City of Eindhoven	22/09/2021

The 10 interviews were conducted with the professionals between May and September 2021. Table 1 above presents information regarding the interviews. While 4 of interviewees played a mainly technical role in the project, 6 of them had mainly a managerial position. All of the interviewees had sufficient knowledge of both managerial and technical aspects of the projects they were involved in.

3. Digital Twin Projects in the Netherlands

This section presents information about urban digital twin initiatives undertaken by both the public and the private sector in the Netherlands based on the conducted interviews. The following aspects were considered in the assessment framework and guided the data collection: general information about the project or company, timeframe of projects, management model, use cases, challenges and next steps.

Municipalities and waterboards are the main public entities currently interested in developing digital twins of the territory under their jurisdiction. In the private sector, some digital twin initiatives aim to reconstitute some aspects of the whole Dutch territory. By translating publicly available data about the built environment into a user-friendly interface, companies have invested in creating national digital twins. For instance, the platform Nederland in 3D offers a comprehensive 3D digital twin solution based on open standards and data integration. It is a result of a collaborative effort between companies with different expertise, e.g. Future Insight (Nederland in 3D, 2022). Another example is the digital twin ***3DNL***, by Cyclomedia, which includes features such as mesh measurements (distance, height, volume), asset management, shadow analysis, solar capacity calculations and building cross-sections (Hexagon, 2021).

Table 2: Urban and spatial digital twin initiatives in the Netherlands.

Project	Territory	Organization(s)	Main Use Cases	Source
Nederland in 3D*	The entire Netherlands	Future Insight, Sweco, Avineon, Nelen & Schuurmans, Cobra, Kavel10	3D Visualization	(Nederland in 3D, 2022)
3DNL		Hexagon and Cyclomedia	Mesh measurements, asset management, shadow analysis, solar capacity calculations and building cross-sections.	(Hexagon, 2021)
3D Maquette		Geodan	Combine and visualize data in 3D.	(Geodan, 2022)
3D Amsterdam*	Amsterdam	Gemeente Amsterdam	City planning	(Gemeente Amsterdam, 2022)
Schiphol Airport Digital Twin	Schiphol Airport	Schiphol Airport	Logistics operation	(ESRI, 2019)
3D Rotterdam*	Rotterdam	Gemeente Rotterdam	Citizen engagement, streamlining permitting process and safety.	(Gemeente Rotterdam, 2022)
Den Haag Digital Twin	The Hague	Gemeente Den Haag and Argaleo	Monitoring pedestrian and biker flows	(OTAR, 2021)
Port of Rotterdam Digital Twin	Port of Rotterdam	Port of Rotterdam	Logistics operation	(Port of Rotterdam, 2022)
3D Digital City*	Groningen	Gemeente Groningen	City planning	(Gemeente Groningen, 2022)
3D Utrecht*	Utrecht	Gemeente Utrecht	City planning	(Gemeente Utrecht, 2022)
3D Stadsmodel*	Eindhoven	Gemeente Eindhoven	City planning	(ESRI, 2021)

Project	Territory	Organization(s)	Main Use Cases	Source
Brainport Smart District Digital Twin*	Brainport Smart District, Helmond	Geodan	Real estate customer experience	(Brainport Smart District, 2020)
Almere Digital Twin	Almere	Gemeente Almere	Improving building permit processes	(Gemeenten-NL, 2021)
Lekdijk Digital Twin*	Part of the surroundings of the Lek River	Hoogheemraadschap De Stichtse Rijnlanden	Infrastructure management	(Geodan, 2018)
Den Bosch Crowd Management Dashboard*	City center of Den Bosch	Gemeente 's Hertogenbosch and Argaleo	Crowd management	(Argaleo, 2019)
Digital Twin Zeeland	Province of Zeeland	Veiligheidsregio Zeeland	Safety	(Argaleo, 2021)
Smart City Alkmaar	Alkmaar	Analyze and Gemeente Alkmaar	City planning, housing provision monitoring	(Analyze, 2022)
Nijmegen 3D Tweelingstad	Nijmegen	Gemeente Nijmegen	Crowd management and planning of big events	(Gemeente Nijmegen, 2022)
Zwolle Digital Twin	Zwolle	Kadaster	Simulating heat stress and rise of water levels	(Kadaster, 2021)
Digitwin Noordzee	North Sea	Rijkswaterstaat, Deltares, Maris, Wageningen Marine Research, Universiteit van Breda, Vrije Universiteit Amsterdam and Marien	Environmental monitoring and policy-making	(DigiShape, 2022)
Tygron Platform*	On-demand	Tygron	Parametric design, transportation planning, flood simulation	(Tygron, 2022)
Urban Strategy		TNO	City planning	(TNO, 2022)

*Initiatives assessed during round of interviews mentioned in Table 1.

4. Comparative Analysis Results

Through the assessment framework, it was possible to have a deeper understanding about the projects listed on Table 1, by holding interviews for data collection. This section aims to present the main results.

Understanding the city context is important to frame and compare different initiatives. This cohort of cities whose officials were interviewed during this research was chosen based on the available information regarding their digital twins and encompasses mostly the biggest cities in the Netherlands: Amsterdam, Rotterdam, Utrecht, Eindhoven and Groningen. All of the assessed cities already have an operating open data portal, enabling downloads. Almost all of them (4 out of 5) also have at least one 3D dataset available for download. It means that Dutch cities already have some maturity in data warehousing and have internal capacity in terms of data management and services before they undertake digital twin initiatives. Many of them also have a ruling smart city strategy, which is capable of framing the Digital Twin project in a broader context of urban innovation.

Out of the assessed public and private digital twins listed in Table 1, most digital twins were found to be operational (7 out of 10), but they are constantly being perfectioned with new functionalities. Most digital twins are multi-purpose platforms (6 out of 10). Those who are still focused on one topic (i.e. crowd management or 3D visualization), are also planning to encompass other topics in the near future. The staff in the projects range between 3 and 20 full-time workers. Most of them have around 10 people working in the digital twin initiative. Non-technical professionals, such as lawyers, notaries, communication experts, are usually engaged in the digital twin projects to meet specific needs, like conformity to privacy and ethical regulations. However, it does not necessarily mean that there is a multidisciplinary collaboration effort.

Almost all initiatives (8 out of 10) started from 2018 on, based on previous GIS/data platforms already existing in the municipalities. Half of the digital twin projects had a budget from €400,000 to €600,000 in the last 2 years to get to the current development stage (5 out of 10), the others range from €100,000 up to some millions of euros in the case of some private platforms. Most digital twins have funding secured for further development and operation in the next few years (8 out of 10). Funding for the digital twin projects usually comes from city budget and research grants from the European Union or the Dutch government.

Regarding their management, municipal digital twins tend to have a more collective management model, even if often not institutionalized. Private companies have a more technical-oriented approach, designed to solve issues arising from the operation of the digital twin. In terms of maturity level, most digital twins are between a 3D visualization platform up to a data analysis platform (7 out of 10). Private platforms, developed and held by companies, are usually more advanced when it comes to incorporating real time data.

According to Griffith & Truelove (2021), DT ecosystems can be understood by the interaction of some types of stakeholders: DT platform/application operator, DT data custodians/owners, DT data service providers, DT data users. These types are listed below and Fig. 1 presents what this ecosystem looks like in the Netherlands based on the interviews.

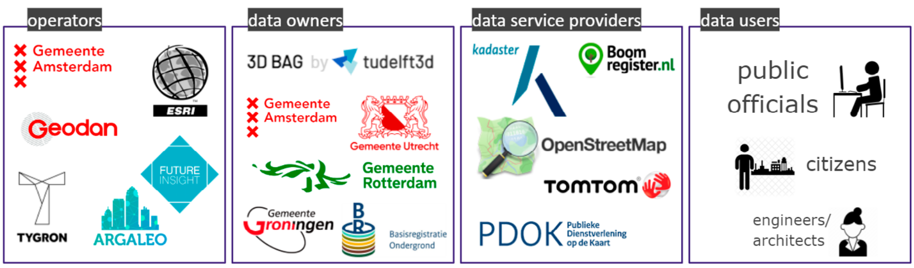
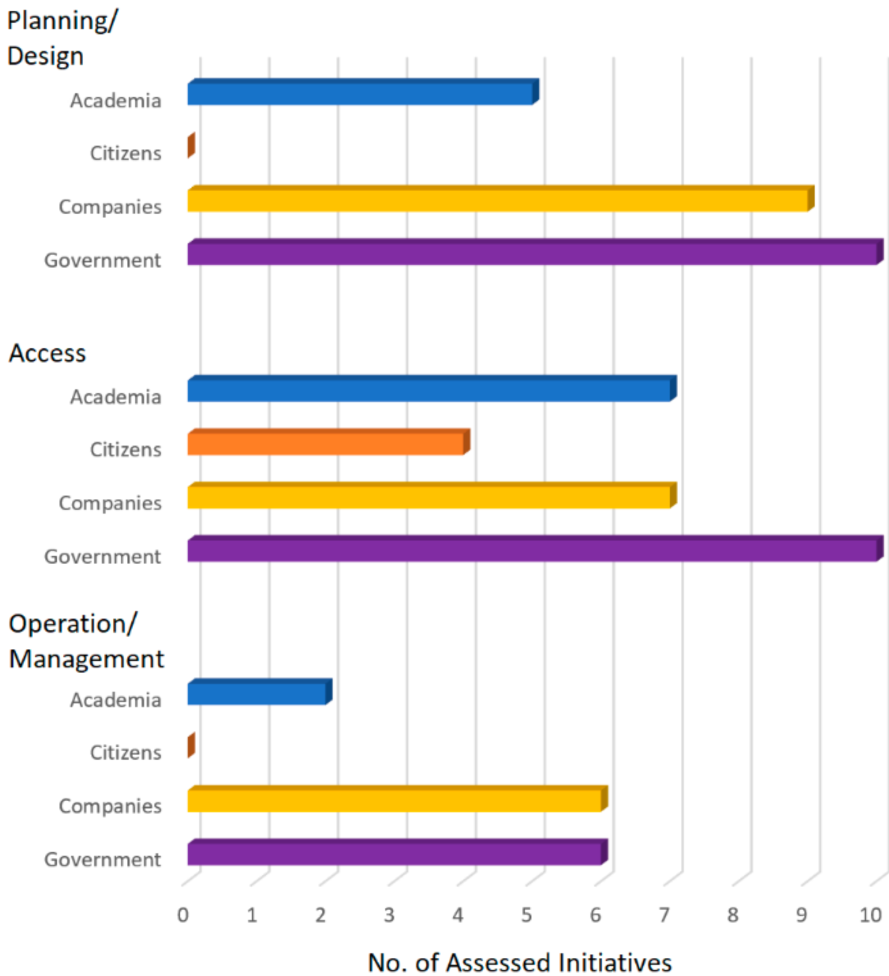


Figure 1: Overview of the Digital Twin Ecosystem in the Netherlands.

Figure 2: Stakeholder Engagement Assessment at different phases of assessed digital twins



According to Schütz, et al. (2019), the Quadruple Helix Model of innovation recognizes four major actors in the innovation system: science, policy, industry, and society. Over time, more governmental institutions are prioritizing greater public involvement in innovation processes. In this study, the projects were assessed in their stakeholder engagement according to this model. Fig. 2 above presents an assessment of the quadruple helix engagement.

Among the assessed projects, the government is always engaged in the design phase, always has access to the digital twin and is very often involved in the management and operation. All the projects have or had partnerships with Dutch universities. Universities and research institutions, when involved in the project, are usually engaged in the design phase, management and operation. The same happens when a company is involved in the digital twin development. The assessment revealed that citizens are not usually engaged in the design phase. They also usually don't have access to the platform (only in 4 out of 10) and were not engaged in the operation and management of the digital twin.

Regarding the technology chosen for the viewer, Cesium was the most used, followed by solutions based on Mapbox, game engines (Unity and JMonkey) and ESRI solutions (ArcGIS PRO). Avoiding vendor lock-in was a concern present in all interviews. Most initiatives do not depend on commercial software, but some use ESRI commercial solutions. Almost all digital twins have cloud-based data storage (mostly AWS and Azure), or are migrating to this type of data storage. Database solutions are diverse (PostgreSQL, Oracle Spatial, Unity Assets, MongoDB, 3DCityDB). The most popular feature in digital twins is the application of queries in one dataset, followed by the ability to export data (tables and 3D) and the application of queries in multiple dataset at the same time. The most common used data formats (in order) were:

- input: tables, BIM files and GIS files, 3D and CAD files and CityGML.
- output: tables, Cesium 3D tiles, BIM and GIS files.

Most digital twins don't offer an API (7 out of 10), only two of the platforms developed by companies and one of the municipalities have an operating API. Most interviewees mentioned that it was on their road map for the next few years. None of the digital twins have a dedicated middleware for IoT, like Kaa, Sofia, Fiware. It reveals that real time sensor data is still being incorporated into these urban digital twin solutions. Practically all digital twins addressed interoperability by using only open-standard data formats. Almost all digital twins don't handle or own any kind of personal data. Only one of the platforms process private information, however the company does not own it, but the municipality. In the assessed projects the Level of Detail - LOD of buildings ranges between 2 and 3.

Concerning the project development process, half of the digital twins that are mainly initiated by the municipalities, started with a vision and principles guiding the process. The other half started from a use case, mainly the platforms developed as commercial solutions by companies. There is usually no framework for a full digital twin implementation. Only one municipality mentioned that the overall architecture was under development.

While half of the procurement processes necessary for the digital twin development relied on traditional procedures, the other half depended on alternative procedures due to the innovative character of the product. It happens because the business and technology environment plays an important role in the project development.

Most digital twins (6 out of 10) already promoted changes in at least one organizational process so far, such as the preparation of 3D base models for new urban design projects and consultation of new information before decision-making. None of the projects included a quantitative measure of the added value of the digital twin yet, but all reported a qualitative improvement of processes. The main challenges facing digital twin initiatives according to the interviews are costs of primary data collection, required organizational change, finding the right use cases, procurement, interoperability between different digital twins.

The next steps of the assessed projects vary within the social, organizational and technical perspectives such as securing more funding for further development, primary data collection, extending GIS functionalities, creating a digital urban community, combining different 3D models, including sensor data, making the digital twin open for everyone, perfectioning calculations and simulations, keeping track of historical data and changes in the model.

5. Conclusion and Discussion

This research showed that 37,5% of the Dutch municipalities with over 100.000 inhabitants (12 out of 32) are working on digital twin projects. They usually aim to bring together the legal, administrative and physical reality; to improve communication between residents and project initiators; to have more insights into the design phase with more data-based scenario creation; and to prepare for the Omgevingswet. When this new environmental code is fully enforced, this integration will be necessary to analyze and deliver permits within a shorter period of time.

It can be concluded from this assessment research that the Netherlands has many urban-scale digital twin initiatives and a vibrant digital twin ecosystem. Many pioneer initiatives undertaken in different cities and organizations have been creating a market for new service providers. Avoidance of vendor lock-in and adherence to standards are a solid consensus among the different projects and Geonovum's national regulation initiative appears to be taking advantage of this moment to propose more specific guidelines towards interoperability.

There is a diversity in use cases, such as crowd management, data visualization, real time monitoring and city planning, but mostly in different initiatives. It is still not common to take advantage of the digital twin potential for a systemic approach: breaking knowledge silos and integrating diverse topics. While most projects have citizens' quality of life as their end goal, it is not clear to what extent they have been benefitting from the digital twins so far. Very often use cases are still being searched after technical development has already taken place. It is also clear that citizens have not been integrated into the design and implementation of digital twins, not even at a conceptual development level.

The quadruple helix model is useful for innovation processes where citizens' needs are central, like in the offer of public services. When lacking participation, citizens play the role of passive recipients or end-users who assimilate the services developed. By missing transparency and input when development choices can still be made, the platform can be underused because it does not fully serve the needs or the innovation itself can be distrusted or repelled by the community.

Making citizens an active part of the innovation system is challenging and a successful method to efficiently integrate a multitude of diverse stakeholders in technology projects that often start as an abstract idea remains a topic for further research. Another question that still requires dedicated research is how to objectively measure digital twin benefits in financial terms or its direct and indirect effects for quality of life through impact assessments. A limitation of the research is that this overview is based on digital twin projects known to the researchers and the conclusions were drawn from projects whose leaders agreed to participate in interviews.

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Best Practices & Case Studies

Exploring city information models & GIS as data via PowerBI

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Abstract

3D City information models have become established geospatial data sets in many cities globally. In addition to existing GIS data, cities are "flooded" with new potential data sources, such as IoT systems, smart mobility devices, digital services and 3D mapping methods like UAV photogrammetry. Tools are needed in the cities for translating the data into insight, and eventually, better decision making. Here, a recent technological development has been the introduction of software tools that attempt to bring data analytics for large user groups.

We present our experiences in utilizing the Microsoft PowerBI business data analytics service with 3D city information models and GIS data, with the aim of testing their applicability with common urban geospatial data. Two test examples from Helsinki, Finland are presented: 1) utilising data from a CityGML model and 2) applying data integration for combining multiple urban GIS assets for including a wider collection of objects. In both cases, we present the utilized datasets, processing pipelines needed for data import and the resulting data exploration dashboards produced.

As a result, two dashboards were created, allowing 1) the exploration of building information from the city information model and 2) for exploring the characteristics of city regions based on GIS data. While producing dashboards from the test data proved possible, it wasn't accomplished without intermediate data processing steps. Further research would be required to verify the usability of produced dashboards, design them for actual use cases and verify the compatibility of the tested platform with further data types.

Keywords
CityGML, PowerBI, data analytics, city model, visualization

1. Introduction

3D City information models have become established geospatial data sets in many cities globally, most typically realized following the City Geography Markup Language (CityGML) specification (Gröger & Plümer, 2012). These models are understood to hold a vital role in both progressing towards a smart city and producing an urban digital twin (Doran & Daniel 2014).

In addition to existing Geographic Information System (GIS) data, cities are “flooded” with new potential data sources. Internet of Things (IoT) systems offer real-time sensor data from e.g. weather conditions, traffic, energy use and the state of the physical infrastructure (Santhanavanich & Coors 2021). Smart mobility devices and digital services produce data concerning people movement and use of services (Yang et al., 2022). Improving methods of 3D mapping, such as Unmanned Aerial Vehicle (UAV) photogrammetry and mobile laser scanning are able to digitize both built and natural environments with increasing efficiency (Li et al., 2022).

Managing the increasing collection of data sources requires modular approaches and standardized elements, such as Application Programming Interfaces (APIs), as suggested for sensor data streams in Soe et al., 2022. Otherwise, organizations risk “data silos”, resulting in inconsistency and lack of synchronization in different data sets (as identified in the digital twin literature, see: Singh, 2021).

In addition to just managing the data, tools are also needed in the cities for translating the data into insight, and eventually, better decision making. This is further emphasized by processes like participatory urban planning, requiring the cooperation of multiple stakeholders, both from professional and citizen domain. This requires tools for both geovisualization (e.g Jaalama et al., 2021) and the visualization of other types of data, if they are to be included in these processes.

Data integration and visualization are strongly present in 3D city modeling (Biljecki et al., 2015). Similar elements of supporting data interpretation are also strongly present in many of the attempts to produce “urban dashboards” during the last ten years (see, e.g. Kitchin et al., 2016). Built for varying purposes, one the common approaches in these dashboards has been the combination of geospatial data with other data describing the objects’ properties, according to the scope of the dashboard (for an energy example, see Urrutia-Azcona et al., 2021). A compilation of urban dashboard examples is provided in Table 1 below.

Table 1. A compilation of urban dashboard examples available in the literature.

Site	Described purpose	Reference
Dublin	"...provides citizens, planners, policy makers and companies with an extensive set of data and interactive visualizations..."	Kitchin et al., 2016
Stockholm	"...support governance of complex urban dynamics in terms of functionalities and land use."	Kourtit & Nijkamp, 2018
Stavanger	"...supports visualization and real-time monitoring of city trends..."	Farmanbar & Rong, 2020
Barcelona / Santander	"...brings together operations, sensor, and citizen feedback data..."	Lee at al., 2015.
Landkreis Ludwigsburg / New York / Wüstenrot	"...visualize different energy data under one application."	Würstle et al. 2020
Yangon	"IoT and Big Data Analytics for Geospatial Solutions Provider in Disaster Management"	Lwin et al., 2020

Here, a recent technological development has been the introduction of software tools that attempt to bring data analytics and creation of highly illustrative and interactive data visualizations to large user groups. Such tools have been introduced by major software companies, including e.g. Microsoft PowerBI (https://powerbi.microsoft.com/en-us/), Salesforce Tableau (https://www.tableau.com/trial/data-analysis-software) and SAS Visual Analytics (https://www.sas.com/en_us/software/visual-analytics.html). In the marketing language of these products, it is emphasized how all of these tools can be applied to data visualization by anyone.

Applying business intelligence (BI) inspired data analytics and visualization to urban GIS is topical for a number of reasons: Firstly, data concerning the urban environment is increasingly available, and most of this data has a geospatial component (in minimum, a position). Secondly, especially with 3D city models, most of the current applications of urban 3D GIS have so far been limited to 3D visualization (as noted by Biljecki et al., 2015), and not much attention has been paid to exploring the data with other means. And, finally, as the aforementioned new tools have become available, and are creating interest in city organizations for applying data analytics and visualization for supporting the city processes. The understanding and insights offered by the data analytics and visualization are hoped to support decision making and thus produce economic benefits. However, for "the data analytical approach" to urban GIS to become feasible with these tools, we have to first ensure the compatibility of these tools with the data encountered in cities. After all, as these tools are coming from the business domain, they aren't necessarily intended to operate with geospatial data. This raises the question whether these already widely used tools could be easily applied with current urban GIS data?

In this case study, we present our experiences in utilizing one of these data analytics & visualization tools (the Microsoft PowerBI business data analytics service) with 3D city information models and GIS data commonly encountered in the urban context. Two test examples from Helsinki, Finland are presented: 1) utilizing data from a CityGML model and 2) applying data integration for combining multiple urban GIS assets for including a wider collection of objects. In both cases, we present the utilized datasets, processing pipelines needed for data import and the resulting data exploration dashboards produced.

2. Materials & methods

Out of the available data analytics & visualization tools the Microsoft PowerBI (https://powerbi.microsoft.com/) was chosen following the interest of the City of Helsinki. Offered both as a free desktop application and as a part of software service subscriptions, it was perceived to be available for a large number of users in the city organization. At the same time, its similarity with some of the MS Office applications was hoped to make it simple to adopt.

As a test data, the open GIS assets from the City of Helsinki were applied, with the used datasets being detailed in table 2.

Table 2. The utilized datasets

Data	Use case	URL
CityGML Level of Detail (LoD) 2 buildings from the 3D city model	Analytical view to CityGML model	https://hri.fi/data/en_GB/dataset/helsingin-3d-kaupunkimalli/resource/577f4286-7162-42e9-8ffe-52632228569e
Road and green are polygons from the register of public areas	Data integration for comparing city areas	https://hri.fi/data/en_GB/dataset/helsingin-kaupungin-yleisten-alueiden-rekisteri
Urban tree database	Data integration for comparing city areas	https://hri.fi/data/en_GB/dataset/helsingin-kaupungin-puurekisteri
Building polygons	Data integration for comparing city areas	https://hri.fi/data/en_GB/dataset/helsingin-rakennukset
District division	Data integration for comparing city areas	https://hri.fi/data/en_GB/dataset/helsingin-piirijako

2.1 Analytical view to CityGML model

For producing a view of the CityGML model with PowerBI, the main task was bringing the model to a format supported by the PowerQuery tool used to import data to the PowerBI platform. The emerging 3D city model encoding format, CityJSON was applied (JSON referring to JavaScript Object Notation, CityJSON utilizing this for storing the CityGML model). The selected test segment of the model was obtained from the download service as .GML and converted to CityJSON with the open converter tool (https://github.com/citygml4j/citygml-tools). After this, the open CityJSON/IO library (https://github.com/cityjson/cjio) was used to combine and reproject the model to the World Geodetic System 1984 (WGS84) coordinates. After this, the resulting JSON files were read with the PowerQuery tool.

Based on the data, an example dashboard was created, visualizing the information present in the city model buildings such as construction year, number of floors and the construction material. The building geometry was discarded, with discretized coordinate positions used instead.

2.2 Data integration for comparing city areas

For producing a visualization facilitating the study of city areas and their differences, several 2D GIS datasets were utilized. The data preparation was facilitated by a set of Python 3 scripts. The datasets were downloaded from the City of Helsinki open Web Feature Service (WFS) server and written out as GeoJSON (https://datatracker.ietf.org/doc/html/rfc7946) files. The data was reprojected to WGS84, and centroid points were obtained for building, road and public green area polygons. After this, the resulting points were matched with the city district division polygons, writing out correlation tables indicating the relationships between objects and districts. Instead of loading the data from a set of files directly to the PowerBI with the PowerQuery tool, the prepared assets were uploaded to a database maintained in the Snowflake cloud service (https://www.snowflake.com/workloads/data-lake/). This was then accessed with the PowerQuery tool.

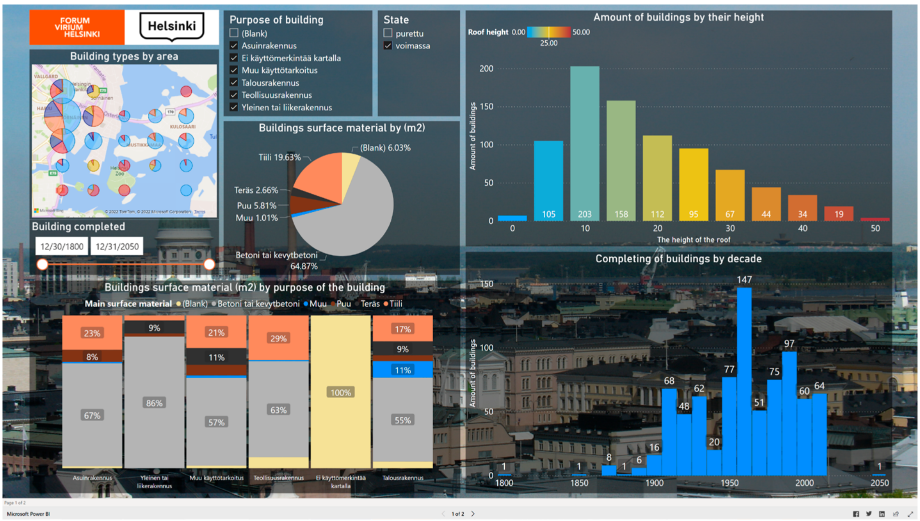
The district polygons were converted to TopoJSON (https://github.com/topojson/topojson) objects for use as “shape maps” in PowerBI visualization. Statistical indicators describing the areas were then obtained for them, relying on the pre-processed green area, road and building polygons and their correlation with the districts.

3. Results

As a result, two public demo dashboards were produced, from the CityGML model (Figure 1) and the city 2D GIS data (Figure 2) respectively. Both of the dashboards can be viewed online, and facilitate interactive study of the data.

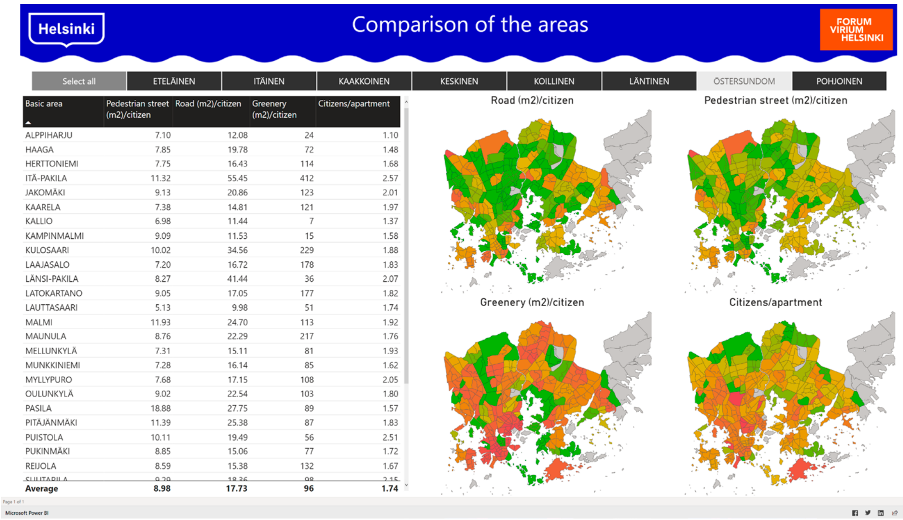
In the first dashboard (Figure 1), utilizing a segment of the Helsinki CityGML model of source data, the user can delve into the details of building information contained in the model. Information concerning the buildings can be queried by purpose of use, height, building facade material or position. This allows the user to identify e.g. parts of the city where older buildings, certain building heights or materials are prevalent. All of this information is present in the CityGML model, but not conventionally visualized by the current model viewers, which typically offer 3D visualization of geometry rather than the data in the model.

Figure 1. A visualization of the data present in a CityGML model. Also available online at: https://fvh.io/buildingsofhel



In the second dashboard (Figure 2), created by combining various 2D GIS datasets, the user can compare different city regions based on their properties. Utilizing a combination of various city registries (Table 2) and the polygons depicting the city's district division, the amount of road surface, pedestrian street and greenery are correlated with demographic information. Thus, the dashboard allows the study of the urban environments' infrastructure offering per citizen. Such data isn't directly available in any single data set at the moment.

Figure 2. A visualization facilitating the study and comparison of city areas. Also available online at: https://fvh.io/areasofhel



Basic area	Pedestrian street (m2)/citizen	Road (m2)/citizen	Greenery (m2)/citizen	Citizens/apartment
ALPPIHARJU	7.10	12.08	24	1.10
HAAGA	7.85	19.78	72	1.48
HERTTONIEMI	7.75	16.43	114	1.68
ITÄ-PAKILA	11.32	55.45	412	2.57
JAKOMÄKI	9.13	20.86	123	2.01
KAARELA	7.38	14.81	121	1.97
KALLIO	6.98	11.44	7	1.37
KAMPINMALMI	9.09	11.53	15	1.58
KULOSAARI	10.02	34.56	229	1.88
LAAJASALO	7.20	16.72	178	1.83
LÄNSI-PAKILA	8.27	41.44	36	2.07
LATOKARTANO	9.05	17.05	177	1.82
LAUTTASAARI	5.13	9.98	51	1.74
MALMI	11.93	24.70	113	1.92
MAUNULA	8.76	22.29	217	1.76
MELLUNKYLÄ	7.31	15.11	81	1.93
MUNKKINIEMI	7.28	16.14	85	1.62
MYLLYPURO	7.68	17.15	108	2.05
OULUNKYLÄ	9.02	22.54	103	1.80
PASILA	18.88	27.75	89	1.57
PITÄJÄNMÄKI	11.39	25.38	87	1.83
PUISTOLA	10.11	19.49	56	2.51
PUKINMÄKI	8.85	15.06	77	1.72
REIJOLA	8.59	15.38	132	1.67
Average	**8.98**	**17.73**	**96**	**1.74**

4. Discussion & conclusions

Utilizing both the CityGML model and 2D GIS for visualization in PowerBI proved to be possible. Dashboards visualizing the data and facilitating the interactive study were produced in both cases, working with both 3D city models and more conventional 2D GIS. However, in both cases, some intermediate processing steps were required to make the data usable on the platform. This is understandable, as the PowerBI isn't intended to operate as a geospatial visualization tool, at least without suitable extensions. Thus, while the production of dashboards proved possible, the process required to accomplish this was less than straightforward, requiring separate tools for preparing the data. This undermines the promise of simple data analytics and visualization with these source data. The visualization capabilities of the platform were also found quite limited in respect to object counts and their geometric complexity. Utilization of city administrative division was possible, but utilization of e.g. building footprint geometries for the entire Helsinki proved too data intensive with over 83 000 objects. Clearly, the platform is best usable with non-geographic data.

When using the CityGML model as a starting point, the detailed semantic information contained in the model can be applied for various correlative analyses, combining e.g. building uses with their materials, construction dates, floor areas etc. Here, the versatility of the JSON encoded city information model, CityJSON, proved highly beneficial for realizing the data processing pipeline allowing the inclusion of the city information model on the data analytics platform.

When a larger collection of existing 2D GIS assets, such as building or vegetation polygons are correlated with statistical areas, it becomes possible to study the city regions based on their multifaceted characteristics. For realizing such analysis, a large number of spatial correlation operations are required to bind various GIS objects together. Existing geospatial processing libraries for the Python programming language were applied to automate these processes.

The resulting dashboards open a new type of view to the information, especially for the 3D city model, which typically is studied through 3D visualization. As a majority of existing applications of 3D city models have focused on their use in visualization (Biljecki et al., 2015), the semantic information contained in city information models has therefore remained an underused resource. Interestingly, the data-oriented view is quite nicely able to support e.g. the study of building materials per construction year. Such non geometric properties are potentially more complicated to visualize in 3D environments than in a data analytics-oriented tool.

At the same time, the limitations of the presented work have to be acknowledged. In the present study, the dashboards were realized as a technical demonstration, and not yet to answer a specific use case. Thus, their utility or usability hasn't been systematically verified with real users and use cases. The same applies for the utility of the combinations of data sources used in the dashboards. The selection of data sources was more motivated by their availability and properties rather than actual analysis needs of the city. From the technical perspective, the data sources used do not represent the full spectrum of geospatial data encountered in the cities. For example, raster data (such as remote sensing based land use raster), digital elevation models, laser scanning data or road network center lines weren't tested. This represents a potential direction for further research and technical development.

Looking at the produced examples, we believe that interactive dashboards describing the properties of the urban environment could support use cases requiring the study of multiple data assets describing the same objects. In the urban context, such situations are encountered e.g. in decision making tasks related to energy use and infill development. However, the development of such tools would require systematic planning and identification of actual analysis needs from the processes. This would most likely require either user research or user inspired design as first steps. In real use cases, it is also possible that the technical limitations of the PowerBI dashboards with geospatial data would create issues. For example, use cases also requiring detailed 2D or 3D visualization would likely have to be realized with a combination of tools, utilizing e.g. Cesium (https://cesium.com/) for geometric visualization.

In pre-processing the data, open formats that can be easily read in programming (e.g. GeoJSON and CityJSON) were found highly useful. Thus, the pre-processing pipelines could be formed by combining a set of existing libraries and utilities, reducing the need of programming from scratch. In effect, they proved to be the “missing link” between the original geospatial data sets and their application on an unconventional platform (from a geospatial point-of-view).

Algorithmic data processing is also significant for creating potential for automation. In the presented experiments, the used datasets were static in nature. If more frequently updating data is to be used in visualization, automated processing and API access become requirements. Several potential tools exist for creating these processes, including no-code “Extract, Transform, Load” (ETL) services (such as FME server, https://www.safe.com/fme/fme-server/), cloud-based data storage and processing systems (such as tools offered in MS Azure suite) and containerized virtual machines (with programming). Thus, the data-oriented views could be automatically provided for relevant data sets belonging to the cities’ spatial data infrastructure.

In a larger context, data analytics-oriented visualization is an example of a new use case coming into the geospatial domain. This emphasizes the importance of modular architecture in systems, rather than monolithic design. In modular spatial data infrastructure, using a suitable combination of open APIs and formats, the new use cases can be integrated to the existing infrastructure expanding the services it provides.

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Best Practices and Case Studies

BIM and IFC through building life cycle

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Abstract

The concept of BIM (Building Information Modeling) has existed since 1970s. In early 2000 BIM started to shape into what it is today. Only in fairly recent years has it become a common and widely used tool in construction.

The IFC (Industry Foundation Classes) data model is a way to describe architectural, building and construction industry data. It is a platform neutral and open file format used to exchange information between project teams.

BIM is a helpful tool to coordinate the design and construction of a building. With the help of IFC files, which are like complex PDF files in 3D, the collaboration between project teams is easy. However, BIM and IFC uses decrease drastically after the building is finished. It is not always time or cost efficient to upkeep BIM throughout the building's life cycle and they can also be a burden if used when they are not really needed.

In some cases, it is necessary to maintain an updated BIM. Such cases include industrial complexes and other buildings that change frequently and where the building itself is an integral part of the operation of the property.

If the best option is to use BIM through the life cycle of the building, there are still several factors to consider; who will update the BIM, when it will be updated, what tools are used, where the BIM is stored etc. BIM is a software-based solution and software used in generating BIMs can change yearly. It is not guaranteed that the BIM generated today will be valid in five years. In addition to the software, also BIM requirements change as the technology evolves.

BIM has undeniable benefits when constructing a building, with Smart Cities and Digital Twins, specific scenarios where it is useful throughout the facility operation, and it also has uses when eventually deconstructing the building. If the BIM is updated properly, all the material and the equipment the building contains are available through BIM. BIM can be used to visualize the deconstruction process, identify recoverable materials and analyze the performance of the building for future reference, among other things.

As BIM is usually used to reflect the current state of the building, IFC can be used as a snapshot tool to record the changes through the life cycle of a building. IFC snapshots can be a useful tool when evaluating the cost and efficiency of various changes to the building. With energy simulation software, IFCs can be used to simulate how a change would affect the energy consumption of a building.

This paper presents cost-effective and practical ways to use BIM and IFC in building projects and through the life cycle of the building. It is a part of Karelia University of Applied Sciences' project Digital Twin - Sustainable Services and Knowledge Transfer in Real Estate and Building Technology that started at the beginning of 2021 and will continue until June 2023.

Keywords
building life cycle, BIM, IFC

1. Introduction

The concept of BIM (Building Information Modeling) has existed since 1970s. In early 2000 BIM started to shape into what it is today. Only in fairly recent years has it become a common and widely used tool in construction.

BIM is a process to gather all the related data regarding a building in one complex model. Information ranging from building's geospatial location to information about a specific valve can be included in the BIM. It can be a powerful tool for a complex building in every part of its life cycle if used correctly. However, since BIM is not a simple process, the extents of its use should be considered at the start of each project.

2. What are BIM and IFC

BIM (Building Information Modeling) is a process for creating and managing information on a construction project throughout its whole life cycle. As part of this process, a coordinated digital description of every aspect of the built asset is developed, using a set of appropriate technology. It is likely that this digital description includes a combination of information-rich 3D models and associated structured data such as product, execution and handover information.

Internationally, the BIM process and associated data structures are best defined in the ISO 19650 and 12006 series of standards. (NBS. 2022)

IFC (Industry Foundation Classes) ***is a standardized, digital description of the built asset industry. It is an open, international standard*** (ISO 16739-1:2018) ***and promotes vendor-neutral, or agnostic, and usable capabilities across a wide range of hardware devices, software platforms, and interfaces for many different use cases.*** (BuildingSmart International. 2022) Generally, it is an uneditable snapshot of a BIM.

In addition to the object geometries, IFC models can include almost all the information defined in the software used to create the model, like materials, power, flow rates or product numbers. It is also possible to add custom information.

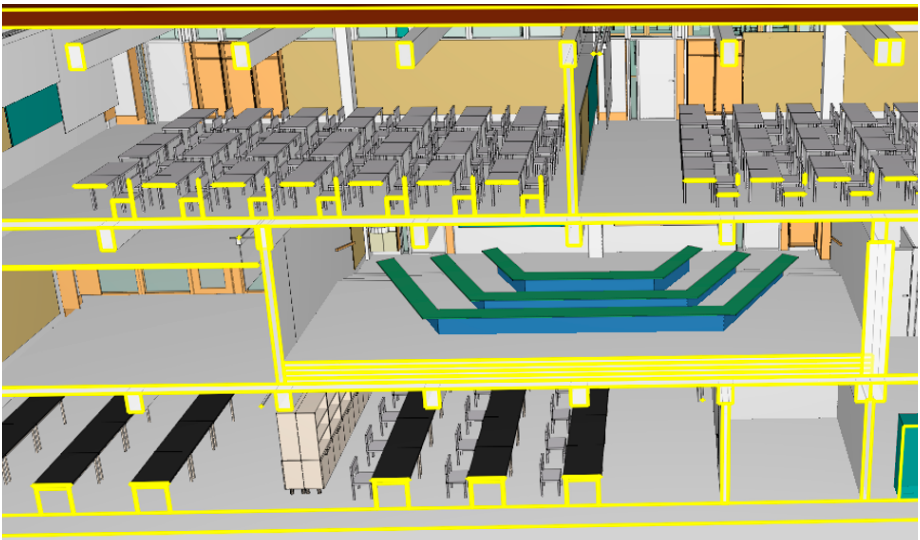

Figure 1. A sliced view of an architectural IFC model.

3. Building life cycle

A building's life cycle consists of four phases: planning phase, construction phase, operation phase and end of life phase. In each of them, BIM and IFC have different uses.

BIM has strong emphasis on the first two phases, while IFC can have uses in all four phases. The scale of use depends on building complexity, frequency of modifying, renovating etc. operations on the building and stakeholder's abilities to use BIM and IFC efficiently.

3.1 Planning phase

The planning phase is the most important phase when it comes to BIM and IFC. It takes time to make a good BIM, but in the long run it also saves time. Sometimes it is even required to have an IFC model in order to get a building permit.

The scope and uses of the BIM should be determined in very early stages of the planning phase. It can be difficult to add information to the BIM parts once they have already been implemented. Correspondingly, if too much information is included in the BIM, it uses time and resources without real benefits. Normally the BIM is implemented in such a way that a sufficiently detailed IFC can be generated to enable energy simulations, carbon emission calculations, cost estimations, quality control etc. Updating the models at regular intervals is a good practice and will keep everyone updated on the status of the plans.

At the start of the planning phase, the stakeholders should determine their requirements regarding the models and verify that the BIM or IFC is compatible with their applications. At this point it should also be determined if there will be benefits of using the BIM and IFC after the building is constructed.

At minimum the various designers can use the IFC for clash detection and quality control. This reduces the problems that can arise during construction. Usually the building services designers do clash detection models even if it is not required and there is no architect's IFC model available. Cost estimation can sometimes be performed from a somewhat simple IFC if the company performing the calculation has sufficient expertise. Higher detail level will of course increase the accuracy of simulations and calculations based on IFC models.

In present complex buildings a good BIM is mandatory to ensure a technically and financially efficient outcome. Accurate IFC coordination between designers helps reduce the redundant space and significantly reduce problems during construction phase. Often the initial draft needs to be changed several times so that the building is structurally, technically and architectonically optimal in every way.

The IFC model helps visualize the building to those who will eventually use it. With the help of VR (Virtual Reality), people working or living in the building will have a better understanding of the building than they would have through traditional plans. Often, they have good views on how the design will work in practice, considering maintenance and other normal building operations.

The applications used to create BIM should be reviewed if the model is to be used beyond construction phase. When it is time to renovate the building, the worst-case scenario is that the applications don't support the original BIM which was created maybe even decades ago. Some ways to handle this problem are periodically checking the compatibility of application updates with the BIM and updating as needed, or making a new BIM when there are enough changes to the building that a new up to date BIM is justified.

3.2 Construction phase

At the start of the construction phase the BIM should be mostly finished. The stakeholders can use the IFC model to schedule the phases of their work in coordination with other stakeholders. Worksite area management, safety, scheduling incoming materials and their storage and supervising the whole construction process are some cases where IFCs extracted from a properly implemented BIM can be helpful.

During the construction phase the BIM and the IFC model need to be updated to reflect the changes made on the site during construction. Correspondingly, changes made to the models have to be made available to all stakeholders as soon as possible so they have the most recent plans. Some minor changes to the model are not necessary to be updated and shared immediately, but at the very least the relevant stakeholders should be informed that such change is expected in the next update. Communication is essential, as some changes might not be updated anywhere and as a result, the model will not be accurate.

At the end of the construction phase and before the building is in-use, all relevant changes should be extracted from various documents and updated into the BIM. The BIM reflecting the finished building is called as-built model. The final updates of the BIM and IFC are not necessary in cases where there will be no use for the BIM or the IFC models after the building is finished. Such cases could be e.g. warehouses. However, the BIM or the IFC should not be discarded in case they might be used in some situations during the operation phase of the building.

In the case where the BIM is to be used through the building life cycle, comprehensive models are necessary. The BIM should represent the finished building as accurate as practically feasible. It should also be considered that later on the BIM might have other uses, like calculating the carbon footprint if it is not done in the planning phase. In the case where a digital twin of the building is made in one of its various extents, it should be ensured that the BIM and IFC model are compatible and usable in the applications used by the digital twin.

Sometimes the building has sections with different uses. Sections that are not expected to change much during the building life cycle can be modeled with less details. One such case could be a building with business spaces in the lower floors and apartments in the upper floors.

The apartments are not likely to change significantly, but the business spaces can change a lot depending on the occupants.

3.3 Operation phase

Operation phase spans from when the building is brought into use to the end of the buildings service life. During the operation phase the building can change several times in various ways.

Buildings like basic apartment buildings, warehouses and other relatively simple buildings do not benefit from highly detailed BIM and IFC models, as the changes are usually minor or relatively straightforward. The IFC model from the construction phase can be used when renovating the building, but it does not necessarily need updating after the renovation. The traditional methods of tracking and updating the changes in plans could be sufficient and more resource-effective, but as the tools become more common and their users more experienced with them, updating the IFC will become a more viable solution.

Commercial buildings, hospitals, industry and other more complex buildings can change significantly during their operation phase. Therefore, it is justified to upkeep and update the BIM and IFC models. The BIM can be used for example for maintenance and in renovations to coordinate the operations. The changes made to the building are updated to the BIM and the users of the BIM always have up-to-date information on the parts they need. Especially in the cases of 3D digital twins, updates are essential so that the data is linked to real and existing properties of the building.

The IFC model can be used to help visualize various aspects of the building, like for example room occupancy, customer flow, storage use, temperatures, energy consumption, security and rental income. All kinds of 3D representations can be done from the model and it is much easier to see the whole situation than from traditional 2D pictures or data tables.

When the BIM is properly done, it can be used to simulate the effects of changes and renovations to the building. Any issues regarding the building that have arisen during the use can be simulated beforehand

and decisions made based on the simulations. For example, if some spaces are too hot during summer, it can be simulated if cooling is required or if smaller measures like window shading would be sufficient. The accuracy of the simulations is relative to the accuracy of the BIM, therefore a well-maintained BIM helps in making more accurate decisions on investments on renovations and changes to the building.

3.4 End of life

It is not often considered that the BIM and IFC models can be useful at the end of life phase of a building. When deconstructing a building, it is more time and cost effective if we know what materials and components are used in the structures and technical building services. The coordination of recycling, reuse, waste component management and harmful substance management can be done well beforehand if comprehensive and up to date data of the building is available.

The case of asbestos is a good example of the benefits of BIM and IFC at the end of a building's life cycle. At the time it was taken into use, it was not known that one day it would become the problem it is today. When we have comprehensive data on the building, even changes in the building regulations or harmful substance classifications will not become an issue in the scale of asbestos.

Research on structural component reuse is being done to reduce carbon emissions. (Karelia 2022) In the future, it could be possible to sell certain structures for reuse in other buildings before deconstruction. This would require planning a few years beforehand so the structures can be sold in advance and transported directly to their new site during deconstruction. Storage of structures and other parts recovered during deconstruction is expensive, so storing everything viable for reuse is not a good option.

Exact measurements are available in the BIM and the condition of the structure can be easily verified by modern sensors. A complete BIM could be published when the eventual deconstruction is confirmed and new building projects could reserve parts of the building for reuse in the new building.

4. Beyond building life

When the building is deconstructed, the use of BIM and IFC models is not over. Through the BIM, assessment of various decisions made during the building life cycle can be done and the best practices put to use in other buildings and in future construction. Did the building services operate as efficiently as simulated and expected, were there any problems with structures, was the initial plan of the building functional or would some parts have needed a different solution? The original and changed BIM can be reviewed and used as a reference in any future construction.

The simulated data and cost estimations can be referenced with the actual outcome of what is built. That data can be helpful when making simulations and cost estimations later on in other buildings. There are always some aspects that can't be simulated or considered and the data will help reduce the cases of unexpected behavior in costs or in the building.

As with all technology, progress happens with innovation and experience. Whenever possible, the use of BIM and IFC should be taken a bit further than necessary to get that experience and gather more information on what is useful and what is not. BIM is relatively new and only through comprehensive use can the most efficient practices be found and the digital aspect of building technology evolved.

5. Conclusions

BIM and IFC are powerful tools throughout the building life cycle, regardless of the buildings size or complexity. Their full potential has not yet been reached due to various stakeholders' ability or interest in using them efficiently. It could be due to the still changing technology or the skill needed to use all the digital tools available. It is obvious that BIM and IFC will be used more every day and they will be the main tool for communicating in construction and building operations, just not necessarily in their current form. Through extensive use and comprehensive studies, the development will be directed in the direction where it will be more useful for everyone.

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Academic Paper

Robot Service as a Smart Click & Collect Solution in the New Heart of Helsinki

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Abstract

Consumer behavior and the business environment are changing rapidly. The Covid-19 pandemic has further accelerated change. The new ways of doing e-commerce are challenging both brick-and-mortar shops and restaurants.

Our study focused on robot's role in customer experience creation in ecommerce click & collect domain as a part of delivery services. There are numerous studies which has advanced benefits of robot related services, but studies of robot's role as part of click & collect delivery systems are scant. The aim of this study was to test a smart Click & Collect solution in a new shopping center in the heart of Helsinki. In practice, the experiment focused on the delivery of restaurant food with the help of a robot from the restaurants of the shopping center to the residents of the hotel, which is located in the shopping center.

The study was conducted in the mall in the summer of 2021, between 6.7-6.8. The study was qualitative in nature and data were collected by many methods (diary, analytics, observation, meeting memos). Robot made altogether 54 deliveries to customers. The data were analyzed by combining the data collected by different methods and raising key observations related to the success of the concept.

Results indicated that robot's delivery raised many positive customer reactions. Hence, robot deliver created positive brand image for the mall. Technologically robot performed generally well (70 %) although it confronted couple of times problems while delivering goods.

Study showed that ecommerce related robotics delivery added clearly value to customer experience and created positive brand image. More research is definitely needed especially with robot performance (i.e. communication abilities), customer-robot relationship and general operational area like ordering system.

Keywords
customer experience, robot, ecommerce, smart city

1. Introduction

Consumer behavior and the business environment are changing rapidly. The COVID-19 pandemic further accelerated these changes. New digital platforms and methods for ecommerce are challenging both brick-and-mortar shops and restaurants. Customers are accustomed to quickly placing orders online, and having them flexibly picked up or delivered. In particular, the number of customers in urban centers and shopping centers has decreased as remote work has increased, and the movement of people in shopping centers has decreased. Even when the COVID-19 global pandemic is controlled, many of these digitized services will remain (Rosenbaum & Russell-Bennett, 2021, p. 262).

One example of service technology advancement is the use of robots in the service context. Robots have many forms and designs (Wirtz, 2018). According to Belanche et al. (2020), robots can contribute to facilitating and enhancing the customer experience. With the help of robots, it is possible to replace human service employees and save on costs (Van Pinxteren et al., 2019, p. 508). Our study focuses on the robot's role and abilities in customer experience creation in the ecommerce click and collect domain as a part of delivery services. Numerous studies have discussed the benefits of robot-related services, but studies on the role of robots as part of click and collect and delivery systems are few. Moreover, many service robot-related studies are conceptual, for example, Čaić et al.'s (2019) meta-analysis of the service robotics research domain. Furthermore, most studies have taken the service organization's perspective, with less focus on the role played by customers. Studies related to actual robot's customer journeys are scant, and research is needed to understand the extent to which service robots influence an end-customer's perspective (Lu et al., 2020, p. 381). Our aim is to contribute to this research gap.

The aim of this study is to test a smart robot click and collect solution in a new shopping center in the heart of Helsinki. In practice, the experiment focuses on the delivery of restaurant food with the help of a robot from shopping mall restaurants to residents of the hotel. The hotel and restaurants are located in the same Mall of Tripla building, the biggest shopping mall in the Nordic countries. The main unit of analysis is the robot's delivery journey from ordering to final food delivery, and our aim is to understand and analyze the critical incidents and the robot's performance during the delivery journey. Our experimental study's aim is mainly practical, but we will also shed new light on the customer interaction/relationships between robots and humans in the delivery context at the theoretical level. The main research question is: How can a robot delivery solution affect the customer experience?

This study is part of an innovation ecosystem development project run by the Haaga-Helia University of Applied Sciences. The project, PasilaHUB, is developing, innovating, and piloting new solutions in close cooperation with local businesses. We are working together toward an urban and exciting city center in the new heart of Helsinki. Over three years, the aim is to pilot ten new business-driven concepts.

Last-mile delivery has become a critical source for market differentiation, motivating retailers to invest in a myriad of consumer delivery innovations, such as buy-online-pickup-in-store, autonomous delivery solutions, lockers, and free delivery with minimum purchase levels (Lim et al., 2017). Consumers care about last-mile delivery because it offers convenience and flexibility.

2. Digitalization and robotics in the click and collect domain

Digitalization offers companies interesting strategic opportunities (Abaidi & Vernette, 2018). One area of digitalization that has grown quickly in recent years is ecommerce (Mäki & Toivola, 2021, p. 12). This growth has been both global and local. Currently, ecommerce represents a significant amount of retail sales and is expected to continue to grow in the future. One critical area of ecommerce is delivery: How can customers get the ordered product quickly and conveniently?

The term "last mile" means the "last stretch" of order fulfillment aimed at delivering products ordered online to the final consumer (Mangiaracina et al., 2019, p. 902). This last part of the logistics process is typically the most expensive, inefficient, and pollution-creating part of the supply chain (Ignat & Chankov, 2020). In the academic literature, B2C (Business-to-Consumer) ecommerce last-mile delivery has mainly been studied according to three perspectives: environmental sustainability, effectiveness, and efficiency. Few papers have addressed innovative solutions, such as parcel lockers, crowdsourcing logistics, and drones (Mangiaracina et al., 2019). Our intention is to bring robotics last-mile delivery solutions with a customer focus to this discussion. In general, the last-mile concept fits well with our research theme because of the relatively short delivery distance, restaurants, and customers located in the same mall building.

Robotics has many roles and meanings in service delivery and digitalization in a broader context. According to Wirtz et al. (2018), service robots can have a physical or virtual representation with humanoid or non-humanoid features, and they may have different types of tasks, such as cognitive-analytical or emotional-social tasks. However, there seems to be no perfect design for a robot. In our case, the Taika (the name of the robot) robot did not resemble a human because its main task was food delivery. To build a positive brand image and make it more acceptable among all customer groups, some human elements were added. The Taika robot had animated eyes, hands, and even cloaks. In general, customer responses to a robot are typically a mix of excitement, wonder, curiosity, or disappointment; people experience a low level of control and face-limited robot abilities (Kunz et al., 2019). We attempted to strengthen customers' positive feelings and reactions to a robot with some human features.

Robotics has been studied from customer and employee perspectives (Wirtz et al., 2018) and as part of self-service technologies (Van Pinxteren et al., 2019). One important dimension of robotics is autonomy. Robots' autonomy may range from none to full, where robots function without any direct input from humans (Čaić et al., 2019). Our robot can be defined as autonomous. Taika needed help when food was placed in its delivery box, but when Taika was on its delivery trip, it functioned without human assistance.

Customer experience is critical in all service encounters. End customers have to interact and participate in service delivery with some mandatory activities (Dong & Sivakumar, 2017, p. 950), such as opening the delivery box or automat with the help of an opening code and removing the goods from the box without human assistance. Hence, there is room for service failure and negative experiences. Belance et al. (2020) found that customers indicated a higher level of satisfaction when they experienced a service failure caused by a robot than when they encountered a failure by a frontline service employee. This finding favors robot delivery.

3. Methods

The study was conducted in the Mall of Tripla between 6th July to 6th August 2021.

The main source of data was observations recorded by the trainee, who accompanied the robot and wrote memos about the delivery trips. Moreover, our trainee monitored the mall and end customers and conducted a short interview after each delivery to analyze the customer's experience. The trainee was advised to write down all customer reactions during the robots' delivery trip. The trainee paid attention to both emotional customer reactions, such as facial expressions, and to the functional attributes of the robot, such as whether elevator use was effortless or whether the robot was able to evade passing mall customers. If mall customers asked something about the robot, this was also included in the delivery report. The average delivery time from order to delivery was approximately 30 minutes, ranging from 20 to 45 minutes. The main attributes that affected delivery time were food preparation time and elevator waiting time. All of these observations were written down immediately after the delivery trip. Altogether, 12 end-customer interviews were also documented after the food was delivered. A short end-customer interview included customers' general feelings and experiences about the delivery itself and the robot's suitability for the delivery process.

Other data sources included meeting memos and other robot ecosystem communication notes. The Taika robot made 54 delivery trips to customers, and every trip was documented based on observations and an interview guide. The qualitative empirical analysis coding list was derived from Wirtz et al.'s (2018) classification model, which defined potential positive and deteriorating attributes affecting customer experience while interacting with service robots. An additional framework for analysis was constructed using Kunz and Heinonen's (2019) paper, which addresses "unknown factors" related to human-robot relationships, such as what kind of value service robots represent for the customer and how people develop relationships with robots.

In our study, we applied a qualitative approach and used mixed methods to gather and analyze the data. Our study was conducted following action research principles in which companies, researchers, and students collaborate closely during the research process (Reason & Bradbury, 2009). Moreover, we underlined practical knowledge, results, and actions throughout the research project. This meant active project communication with all project participants daily. Action research, in general, requires researchers to work with practitioners so that research and practice aim to create results together (Lim et al., 2018).

Our analysis followed the aims and framework of the study. A loose coding list was created and used as a basis for diary data analysis. The data were categorized according to the following themes: general findings related to the robot delivery concept, specific robot-related attribute analysis, customer reaction findings, and confronted development issues. We used the above-mentioned process as a basis for data analysis in order to avoid data overload (Miles & Huberman, 1994).

4. Findings

In general, customers (end customers and mall customers that the Taika robot confronted during its delivery trips) had a positive or neutral reaction to the robot.

Some mall customers were scared when they confronted the Taika robot, but this only happened when Taika approached customers without warning, for example, from behind. In general, robots may scare customers if they are too human-like in appearance (Belanche, 2020). Our robot had a limited human appearance.

4.1 Robot operations

4.1.1 Ideas about the function and tasks of a robot

Our robot's role was to deliver goods to hotel customers. The task of the robot was not clear to many of the mall's customers:

- A man asked, "Is Taika cleaning the floor?"
- A woman asked, "What is Taika doing?"
- A boy asked about the name of the robot.

Many mall customers thought that the Taika robot was a cleaning machine, and some asked about its purpose.

4.2 Robot delivery operations

In general, the Taika robot performed relatively well. It carried the deliveries to customers; for example, it did not hit any mall customer during the delivery trips, and it was capable of finding the route that was determinate. However, Taika confronted some problems:

- The peep-sound of the robot was too loud.
- When the order was placed in the robot's system, it did not start; we had to restart it.

4.3 Robot interaction and customer relationship

Customer reactions, interactions, and experiences are critical attributes of robot concept evaluation. There were several customer groups in the mall environment, and many of them had ideas, reactions, or experiences regarding the Taika robot.

4.3.1. End customers

The customers who ordered the food that Taika delivered are the most important group and unit of analysis:

- The customer was happy with the delivery.
- Some technical challenges occurred. The customer was informed that the delivery can be picked up at Scandic-hotel (not the hotel where Taika is operating); however, the customer was satisfied.

4.3.2 Other mall customers and robot delivery

Tripla Mall is crowded with end customers. From a branding and appeal perspective, their reactions are important. In general, their reactions were positive, and many people wanted to take a picture of Taika or of them standing with Taika. Moreover, mall customers were curious and asked many questions about Taika's role and tasks. These were positive reactions because it is essential to generate excitement among customers and gather customer feedback for further development (Lu et al., 2020).

4.3.3 Children

Small children at the mall were categorized into a separate group because of their reactions and behaviors. In our analysis, this group had strong positive feelings toward Taika, but their behavior also caused challenges for robot delivery.

- Kids showed interest in Taika while it was at the charging station; they also touched the robot.
- A kid stood in front of Taika while it tried to turn.
- Kids started to follow Taika. Even a baby started to crawl after Taika...

Even though most children were curious and interested in Taika, they may have challenged its ability to operate independently.

4.4 Logistics performance

In last-mile logistics performance, delivery speed is the second most important factor from the customer's perspective (Ignat & Chankov, 2020). We measured the delivery performance time at three separate points in the customer and delivery journey: the place of the order, the pick-up time of the food, and the time when the customer got the product. The typical timeframe from ordering to delivery was approximately 30 minutes, which was the time required to prepare the food. The actual delivery typically took around 15 minutes, depending on the restaurant chosen and some other variables, such as the elevator status.

In general, robots' service failures can be categorized as technical failures (e.g., problems with hardware or software) or interaction failures (e.g., problems communicating with humans and the environment) (Lu et al., 2020). We confronted some technical failures; for example, sometimes the Taika robot thought it was in an elevator, but it was not, which caused delays in the delivery process. Communication failures were few, even though Taika's communication (jokes) sometimes did not match the situation.

4.5 Service and other development ideas for the robot

The Taika robot's development group discussed many additional tasks for robots. Some development and new task ideas also came directly from customers. One challenge for robot operations is to utilize robots for multiple tasks, in addition to deliveries. Multitasking robot design will make the concept more profitable and effective. The robot's technical performance and communication skills were also part of the development process.

5. Conclusion, limitations, and future research

The aim of the study was to test a smart click and collect solution in a new shopping center in the heart of Helsinki. The main research question was as follows: How can a robot delivery solution affect the customer's experience? The results indicated that the robot's delivery elicited many positive customer reactions.

End customers were mainly satisfied with the robot's delivery. This finding was in line with previous studies, which found that customers had more positive feelings, even in a service failure situation, toward a robot than toward other humans.

The study did not include the financial aspects and profitability of robot delivery operations. Another limitation of the study was the limited timeframe of the piloting period; hence, the results cannot be generalized, and more robot delivery experiences are needed.

The study showed that ecommerce-related robot delivery clearly added value to the customer experience and created a positive brand image. However, more research is definitely needed, especially with regard to robot performance and customer-robot relationships.

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Practices and Policies for Promoting the Circular Economy

Case CECI – Citizen involvement in circular economy implementation

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Abstract

In addition to institutional and political decisions and recommendations, practical solutions are needed to involve citizens in the circular economy. The sharing of good practices between different regions can facilitate the implementation of sustainable practices and improve regional policies for further development. This case study presents a successful example of a European project in which citizen involvement in the circular economy has been supported in a cooperative network between six regions.

Keywords
Citizen involvement, Circular economy, good practices, Interregional cooperation, Policy change

Introduction

The sixth Intergovernmental Panel on Climate Change (IPCC) assessment report, 'Climate change 2022: Impacts, adaptation and vulnerability', draws an alarming image of ongoing changes in climate, ecosystems and biodiversity and the speed of those changes (IPCC 2022). The earlier sixth IPCC assessment report, 'Climate change 2021: The physical science basis' (IPCC 2021), states that human influence has warmed the atmosphere, ocean and land and that widespread and rapid changes in the atmosphere, ocean, cryosphere and biosphere have occurred. In light of these reports and studies, all possible measures to slow global warming must be taken quickly and on many different levels.

The sustainability transition is underway thanks to several important decisions at the strategic and policy level. On the European level, the European Commission's 'Green Deal' (European Commission 2019), the 'Circular economy action plan' (2020) and the 'Fit for 55' legislative climate package (2021) have set up the framework for action at the European Union (EU) level for the coming years; national-level roadmaps and action plans are also underway. All these measurements are necessary to ensure the right direction of rapid climate actions. Alongside the institutional and political decisions and recommendations, however, practical grassroots solutions and measures are also necessary to ensure the fastest possible transition from a linear to a circular economy, which is among the main building blocks in the transition to more sustainable consumption and society. In a circular economy, consumption is based on services rather than on producing new items (Sitra 2022a).

Sustainability and Circular economy

The European Commission's 'Green Deal' (2019) is an important step towards a cleaner and more sustainable environment. The new growth strategy also emphasises the circular economy and the involvement of residents in its implementation. Such an economy is necessary to move from a linear and wasteful economic model to one in which materials and value remain in circulation (Hellström & Porevuo 2020). In a circular economy, economic growth is redefined by being decoupled from the consumption of resources (Lazarevic & Valve 2017, 60). Accordingly, EU legislation focuses on sustainability and the circular economy.

The transition to a more sustainable economy is also progressing on national levels. Finland is a forerunner in promoting the circular economy, with the first national circular economy roadmap emerging in 2016 (Sitra 2022b). The Finnish Ministry of the Environment recently published its new 'Strategic Programme to Promote a Circular Economy' in January 2021 (Finnish Ministry of the Environment 2021). The programme states that the circular-economy market can be strengthened by improving the appeal of circular-economy services and increasing citizens' awareness of such services. The ministry aims to develop new and inspiring ways to gather information on circular-economy services, such as sharing platforms and repair/resale services (Finnish Ministry of Employment and the Economy 2021, 8-9.)

Pursuing a circular economy can help to achieve a more sustainable future. The concept of sustainability originated from concerns about damage to the natural environment caused by technological and economic development after the world wars (Du Pisani 2006, 87). To achieve sustainable development, all three pillars – environmental, social and economic sustainability – should be balanced (World Commission on Environment and Development, 1987).

Environmental sustainability, which is related to fighting the challenges of climate change, pollution and biodiversity loss, includes limiting human activities within the carrying capacity of the ecosystem related to materials, energy and land/water usage (Olawumi and Chan 2018, 232). **Economic sustainability** includes the efficient use of both renewable and nonrenewable resources while aiming for operational profit and the pursuit of reuse and recycling (Goodland 1995, 9; Olawumi and Chan 2018, 232). **Social sustainability** concentrates on humans and communities, with the aim of decreasing inequality. The social-sustainability perspective also implies social equity between generations (World Commission on Environment and Development 1987; Goodland 1995, 2). Related to the circular economy, the social objectives include the sharing economy, the participation of citizens in decision-making, the encouragement of community use and increased employment (Korhonen et al. 2018, 41). Until recently, circular-economy research prioritised the economic and environmental perspectives while focusing less on the social aspects (Geissdoerfer et al. 2017, 762).

In a sustainable circular economy, all aspects of sustainability should be considered. When focusing on citizens and residents, the social perspectives of sustainability become central. This article presents a case study of an interregional project in which citizen involvement and the social aspects of the circular economy were developed through the exchange of experiences and good practices. The aim is to improve regional policies, through which the circular economy can be better supported at the regional level in the future.

Interregional cooperation and exchange for policy changes

The CECI project, co-funded by Interreg Europe, raises awareness of the circular economy and highlights the importance of citizen engagement (Interreg Europe 2021a). The aim of the project is to inspire citizens to adopt sustainable consumption habits and behaviour patterns by promoting new sustainable services, for example the sharing economy and lengthened product life cycles. CECI also encourages citizens to engage in waste reduction, energy savings and circular thinking.

Among the main aims of the CECI project is knowledge transfer within the six European regions in which the project is implemented. A total of eight partners (two from Finland, two from France, and one each from the Czech Republic, Spain, Bulgaria, and Belgium) cooperate and exchange knowledge, experiences, and good practices. Activities include interregional learning through thematic workshops and studies, policy discussions and site visits. The emphasis is on local and regional cooperation between public, third-sector and private actors, with the goal of supporting each region in generating circular-economy strategies and solutions where citizens are at the centre. The main project outcomes are action plans for policy development in all six regions (Interreg Europe 2022a).

The regional action plans specify the required actions to reach the overall project aims. Each participating region designs its own action plan for policy changes to boost the role of citizens in the circular economy. The focus of these action plans is tailormade to solve the most urgent topics selected by regional stakeholders and authorities. These plans are inspired by the shared solutions and good practices on citizens' roles in implementing the circular economy identified in other project partner regions.

A ‘policy change’ refers to a structural change of a policy instrument, the improvement of its management or the funding of a new project that addresses citizen involvement in the circular economy. The fundamental aim of Interreg Europe projects, including CECI, is to achieve a policy change, primarily via structural funds but also through other policy instruments, including regional strategies. Five policy changes had been achieved by late April 2022. All five are new regional projects that advance various means of citizen involvement in the local circular economy. Examples include a creative industry circular hub, the collection and recycling of disposable textiles and citizen/enterprise co-design of new sustainable services.

Sharing good practices to improve regional strategies

As noted earlier, because citizens play an important role as customers, consumers and buyers of products and services, they are important actors who should be considered and involved in the design of regional circular-economy strategies and roadmaps.

During the first CECI interregional meeting, the project partners and stakeholders worked together to define CECI good practices. They identified numerous good practices, including services, technologies, ecosystems, new business models that include citizen involvement, changes in regulations, and educative actions or co-creation events.

The project partners brainstormed the key and guiding criteria for the CECI good practices. Good practices must promote the circular economy, resource efficiency and citizen involvement. They also need to be successfully proven in practice, easily transferable and adaptable to other European regions, and sustainable from an ecological, economic and/or social perspective. The guiding criteria include raising awareness, being attractive to communities and citizens, minimising waste and increasing cooperation between regional stakeholders.

These good practices are connected to reuse, repair, upcycling and sharing to extend product life cycles. At the same time, they emphasize social sustainability together with third-sector organisations and building community around the circular economy. The good practices collected promote citizen education and raise awareness of how everyone can contribute to a circular economy, for example through various food-waste and zero-waste campaigns (Interreg Europe 2022b). One good practice from Finland is a Library of Things, located in a public local library (Interreg Europe 2022b). The Latido Verde store in Spain is an example of a good practice that combines textile recycling with social employment opportunities (Interreg Europe 2022b). Examples of good practices that encourage citizens to participate in local decision-making are participatory budgeting in Lahti, the Open Forum for Transparency and Active Listening in Aragon, and the urban living lab Stroom in Mechelen (Interreg Europe 2022b).

All the CECI partners identify existing good practices in their regions, which are then exchanged among the partners and shared with a wider audience via the project website. This exchange also includes knowledge-sharing through various thematic workshops in which the regional stakeholders can hold discussions, ask specific questions, and obtain answers and more in-depth information. As an outcome of this capacity-building, and from being inspired by already-existing and tested examples from other regions, the partners then design their own regional action plans to boost citizen involvement in the circular economy.

As of April 2022, a total of 64 good practices had been shared between the project partners and on the project website (Interreg Europe 2022b). Participants have organised several regional workshops for a wider audience and two thematic workshops for project partners and stakeholders, as well as publishing the results of two thematic studies and reporting on five policy changes.

Thematic studies to bring better understanding

The first thematic study, conducted in spring 2020, focused on mapping out how citizen involvement in the circular economy is included in existing strategies and implemented in grass-root activities. The study outcomes were summarized in three articles. The first article, which focuses on triggering dialogue with citizens, includes tips and two inspirational examples (Miller et al. 2020a). The second article summarizes the policy situation of circular-economy strategies based on an online survey among CECI partners that was conducted in April 2020. The survey explored related strategies on three levels (national, regional, and municipal) as well as measures for better collaboration between authorities, businesses, and citizens (Virtanen et al. 2020). The third article focuses on the prerequisites and challenges of successful citizen dialogue (Miller et al. 2020b).

Textiles are the topic of the second thematic study, based on the needs and interests of all project regions. The selection of textiles was connected with the fact that from 2025, the revised EU Waste Framework Directive will impose a legal obligation to separately collect textile waste in the EU (Directive [EU] 2018/851). In Finland, this obligation will already be in force by 2023 (Ymparisto.fi 2021). The results of the second thematic study were presented in four articles. The first article's focus is citizen engagement in textile waste reduction; in summer 2021, a dedicated circular-textiles survey was conducted among the project partners (Pichlova et al. 2021a). The second article examines the role of sustainable design and public procurement to reduce textiles waste (Pichlova et al. 2021b). The third article investigates the state of the art among circular textiles in selected European regions (Villanen et al. 2021a). The outcomes of the thematic study, including the opportunities and challenges of new circular businesses, are presented in the fourth article (Villanen et al. 2021b).

Discussion

This article explains the efforts of how citizen involvement in circular economy have been promoted in the CECI project. The aim of identifying and sharing good practices, and thereafter supporting policy changes have been proven successful as new projects, inspired by other region's examples have been born. However, due to regional differences in the operation environment, all good practices cannot easily be transferred. For example, some good practices are based on volunteer work that might be challenging to initiate. In some cases, such as considering recycling of textiles, the enthusiasm and readiness of residents to act is at a higher level than what current technologies can do. Thus, the good practices collected are largely similar.

As Korhonen et al. (2018, 41) have defined, the social objectives of the circular economy comprise, for example, the sharing economy, the encouragement of community use and increased employment. These elements are identified in several of the good practices identified in CECI (Interreg Europe 2022b). The Finnish Library of Things support the sharing economy and community use, whereas the Spanish store promotes social employment opportunities. Korhonen et al. (2018,

41) also points out that the social objectives of the circular economy should promote the participation of citizens in decision-making. Such examples were found in Lahti, Aragon and Mechelen.

In many environmental aspects the city of Lahti and the Päijät-Häme region are undoubtedly ahead of several other European countries, this was confirmed during the three-year CECI project. However, from Finnish point of view, in the context of cooperation and visits, interesting solutions for the circular and sharing economy were introduced in all other partner countries. In addition, it was underlined that in some European regions and countries there is still lots of work to be done in basic waste management alone. On the other hand, lessons were learned about the power of organizations, volunteers, and campaigns. The collaborative work done with enthusiasm and big heart can deliver visible results even in cases where the structural conditions are not fully in order.

Results and future plans

One of the important lessons of the project is that many tried-and-tested solutions related to the local-level circular economy already exist and can help to solve regional challenges, accelerate the transition towards circularity and find new ways to involve citizens in the process. Especially the regions that lag behind, can benefit from the work done and lessons learned elsewhere but the pioneers benefit also from the insights of others. Interregional cooperation, the ability to learn from each other and the sharing of improvements are crucial and should be promoted to benefit from these solutions.

Policymakers and decision-makers have often discussed the role of other actors, including governments, municipalities, businesses and the third sector, but they have yet to focus on the role of citizens. Their role could be of great value, not only as passive followers of the recommendations but also actively, through their everyday life activities. Engaging citizens and elevating their role in regional strategies and roadmaps is therefore paramount and should be included in all levels.

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Best Practices and Case Studies

Case BIOREGIO – Boosting Bio-based Circular Economy

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Abstract

The concepts of bioeconomy and circular economy are well known in the EU. They have similar targets, and they overlap, but neither is fully part of the other nor embedded in the other. A comprehensive circular economy is not possible without the bioeconomy. Though the bioeconomy relies on biological resources, it is not always circular or sustainable; therefore, there is a strong reason for designing bioeconomies with circularity at heart. As many synonyms exist, we can define a bio-based circular economy as an intersection of the bioeconomy and the circular economy.

The Interreg Europe co-funded project BIOREGIO – Regional circular economy models and best available technologies for biological streams – has been developing bio-based circular economies in six European regions. Since 2019, eight partners (two partners from Finland, Spain, Slovakia, two from Greece, Romania, and France) have been cooperating and intensively exchanging knowledge, experiences, and good practices.

By identifying and sharing already-existing and tested solutions, the move towards a bio-based circular economy can be accelerated. BIOREGIO partners have identified nearly 50 inspiring good practices that helped them design six regional bio-based circular economy action plans to solve regional policy challenges. BIOREGIO and Interreg Europe aim to go beyond the involved project partners by encouraging other regions to adopt these good practices. To do so, carefully selected examples with the highest potential for transfer to and adoption in other countries are shared on a freely available Policy Learning Platform. BIOREGIO has contributed over 30 examples to the database.

Thanks to a project extension, BIOREGIO's additional activities will continue boosting bio-based circular economies, in part helping to overcome the impact of the Covid-19 crisis. BIOREGIO's additional activities will assist the regions in this recovery period by enhancing regional development and resilience with new projects and renewed strategies.

Keywords
Bio-based circular economy, Bio circular economy, Circular economy, Policy development, Good practices

1. Introduction and terminology

The circular economy (CE) as an umbrella concept has become more familiar since 2012, when the Ellen MacArthur Foundation introduced it to the public. The CE is understood as a regenerative economic model that differs from the traditional and more well-known linear economy. The foundation behind the idea of a CE is the effective use and recycling of resources (Merli et al. 2018, 713). The circular economy refers to an economic system that aims to close material loops and reduce the need for raw materials and waste disposal while maintaining the value of products and resources for as long as possible (Geng and Doberstein 2008, 232; Ellen MacArthur Foundation 2013, 22; Ghisellini et al. 2016, 12; Kirchherr et al. 2017, 228).

A CE can be described using technical or biological cycles. The technical cycles comprise recycling, reusing, and prolonging products' lifespans before disposing the material, while the biological cycle aims to keep nutrients circulating for as long as possible (Ellen MacArthur Foundation 2013, 24).

The CE has been an essential part of EU policies since the European Commission (EC) presented a flagship initiative on resource efficiency in 2011 (EC 2011). It highlighted the development of a long-term framework, a 'strategy (roadmap) to make the EU a "circular economy", based on a recycling society with the aim of reducing waste generation and using waste as a resource' (EC 2011). The development of the CE concept in Europe was supported by the Ellen MacArthur Foundation. In 2014, the EC launched the Zero Waste Programme for Europe, further promoting CEs (EC 2014). In 2015, it was followed by the first EU action plan, Closing the Loop – An EU Action Plan for the Circular Economy (EC 2015), which emphasised the role of the regions in developing the CE. At the same time, the development of the European bioeconomy strategy (EC 2012) also affected the policy discussion linked to the sustainability discussion.

Related to but separate from the CE, the bioeconomy and the bio-based CE also need to be defined. These two concepts are frequently used synonymously (Pfau et al. 2014, 1223–1224); however, they have slightly different meanings. The term bioeconomy is usually used when defining the concept in relation to biotechnology or technologies and applications comprising a specific part of the existing economy (Staffas et al. 2013, 2756). Conversely, the term bio-based economy is used when referring to an economy based on the use of biomass resources instead of fossil-based products. A bioeconomy does not necessarily support sustainability, as bio-based production is not always sustainable (Pfau et al. 2014, 1242–1243). Additionally, on the strategy level, sustainability was seldom a driving force behind bioeconomy strategies from 2008 to 2012; instead, economic growth played the most central role (Staffas et al. 2013, 2765–2766). However, later on, during the last decade, the bioeconomy has adopted more sustainability aspects (D'Amato et al. 2017, 724). The concepts of the bioeconomy and the bio-based economy are the main background elements in understanding the biological cycles of CEs. In this paper, we define the bio-based circular economy as an intersection of the bioeconomy and CEs.

2. Policy development through experience exchanges

This paper presents a case study on developing bio-based circular economies in selected European regions. The project BIOREGIO – Regional circular economy models and best available technologies for biological streams – is co-funded by the Interreg Europe programme 2014–2020. The project connects eight partners from six regions – Finland (two partners in Päijät-Häme), Spain (Castilla-La Mancha), Slovakia (the Nitra self-governing region), Greece (two partners in Central Macedonia), Romania (Sud Muntenia), and France (Pays De La Loire) – to develop regional policies supporting bio-based circular economies. The project was divided into two phases. Phase 1 (January 2017–December 2019) was an active cooperation phase, and Phase 2 (January 2020–December 2021) was a follow-up of action plan implementation (BIOREGIO 2022a).

Image 1. A bio-based circular economy is a bioeconomy with integrated circular economy principles. (Source: Oona Rouhiainen)

Triggering policy changes and better implementing structural funds and other policy instruments in the EU regions is an overall aim of the Interreg Europe programme. Policy changes can take three forms: (1) implementation of new projects, (2) changes in the management of a policy instrument (improved governance), or (3) changes in the strategic focus of a policy instrument (structural change).

To better prepare for the development of relevant regional policies to support bio-based circular economies, various policy-learning activities at the interregional and regional levels were performed. Thanks to this learning process, policy changes can be generated in the participating regions.

At the beginning of the project, regional stakeholder groups were formed in all project partner regions, with members representing public authorities, academia, companies, and associations. The stakeholder groups meet regularly, at least twice a year, to support the project's successful implementation and increase the chance of achieving policy changes.

The initial activity was to gather so-called good practices – concrete examples or solutions of bio-based circular economies that have been already tested and successfully proven in practice in all partners' regions. Regional stakeholders may be instrumental in the identification of existing regional examples. These practices aim to inspire other regions to adopt them and become the foundation for regional bio-based circular economy action plans.

The relevance of selected good practices and their exchange between project partners is largely dependent on criteria quality and a variety of examples. In 2017, at the first interregional meeting in Lahti, Finland, the criteria for good practices were defined by the BIOREGIO partnership (Interreg Europe 2017).

BIOREGIO good practices include various solutions and technologies – such as biogas production, biorefinery, and bio-waste utilization – or cooperation models, including ecosystems and networks, which support bio-based circular economies. Altogether, eight criteria for good practices were commonly identified: (1) Promotes a circular economy, (2) is related to biological materials, i.e. bio-based materials, (3) promotes social and environmental sustainability, as well as economic growth, (4) is resource-efficient and economically feasible, (5) minimizes waste according to the waste hierarchy directly or indirectly, (6) encourages closing loops and emphasising longer cycles/cascades, (7) preferably includes joint actions (discussions/cooperation/business) among different stakeholders, e.g. Research, Development and Innovation, government, companies, and consumers, and (8) is transferable to and scalable for different European regions (Interreg Europe 2017). During Phases 1 and 2, 47 tried-and-tested good practices were identified by BIOREGIO partners and are available on the BIOREGIO project website (Interreg Europe 2022b). One example of a good practice is a regional roadmap towards a CE for the Päijät-Häme region, which is a regional strategy set up in close collaboration with stakeholders (Interreg Europe 2018a). Another example is a demonstration-level biorefinery, CLAMBER, which focuses on research and development in the Castilla-La Mancha region of Spain (Interreg Europe 2018b).

After a good practice is submitted to the project website, it is assessed by Interreg Europe experts. If a good practice has the potential to be easily adapted and transferred to other regions, it is published on the Policy Learning Platform, an online Interreg Europe database for sharing expert-validated good practices from the EU. Furthermore, the platform encourages EU-wide policy learning and networking by organising thematic events, issuing publications on relevant topics, and enabling peer reviews. Access to the platform is free and offers benefits to registered community members (Interreg Europe 2022c). Out of the 47 identified BIOREGIO good practices, over 30 are listed in the database.

Exchanges of knowledge and expertise related to bio-based CEs have occurred during numerous activities. Every six months, an interregional meeting is hosted by one of the project partners. The meetings include related policy development discussions, site visits to selected good practices, the introduction of the partner's region, networking, and experience exchange with the local stakeholders. Each partner may bring three stakeholders from their region to these meetings. The selection of these stakeholders was carefully done based on the planned site visits and the meeting topic. This enabled a productive debate and exchange of experience between the participants on the topic of bio-based circular economies. The participating stakeholders then acted as BIOREGIO agents in their home countries, both in their own organisations and among the regional stakeholder group members.

Multilevel interregional policy learning has been achieved on the individual, organisational, stakeholder, and external levels. Individual learning has occurred through the active participation of project partners, authorities, and stakeholders in project activities. Through internal meetings and the sharing of information within the project partners' institutions, organisational-level learning has been achieved. The process of stakeholders' learning occurs throughout the project duration, as members of the regional stakeholder group participate in interregional meetings. Finally, the project results and good practices are shared externally in the project regions as well as on the EU level through, for example, the Policy Learning Platform.

In addition to the interregional, regional stakeholder, and institutional meetings, other policy learning events, such as policy discussions, workshops, and regional dissemination events, were held and were open to a wider audience with the aim of raising public awareness and communicating experiences.

3. Results and discussion

During the project, papers by experts, policy reports, and policy briefs were generated as a joint effort of all partners to support action plan development in all project regions. In 2017, a qualitative analysis of national and regional CE strategies was conducted in selected EU countries (Vanhamäki et al. 2019). Most of the investigated national and regional level strategies embraced the added value of CE, through objectives concerning e.g., waste management or bioenergy. The analysis of the situation showed that bio-based CE was hardly ever included as a term in the strategies, however, circularity aspects were referred to, for example, through biowaste management. Based on the outcomes, the first policy brief on bio-based CEs in Europe was published in September 2018. The policy brief highlighted the importance of strengthening the circularity and sustainability perspectives of the bioeconomy. (Interreg Europe 2018c.)

In December 2018, the BIOREGIO policy report on instruments to connect biological streams, research results, and investors was published, compiling the CE practices of biological streams within current state regional policies to enhance interregional learning. In the report, the project partners reviewed the available policy instruments with the potential to facilitate the transfer of research results to industry and businesses operating in the field of bio-waste and biological streams (Interreg Europe 2018d). In 2019, the initial report was revised and the summary report on policy development was published (Interreg Europe 2019a).

The analysis of implementing circular economy in regional policies was updated by project partners. Based on this analysis, the second policy brief on systemic change in national and regional circular economy transition was published in October 2019 (Interreg Europe 2019b). The policy brief stated that all involved regions, and respective countries, except for Greece, had CE included in their policies.

Through interregional learning and knowledge exchange, BIOREGIO enabled the design of regional action plans with a focus on bio-based circular economies in all project regions. In total, six regional action plans with region-specific actions were elaborated during Phase 1. In Phase 2 of the project, the implementation of the regional action plans was monitored and reported. BIOREGIO has achieved a total of nine policy changes, five of which are related to structural funds and four to regional policies. The policy changes include, for example, new funded regional projects related to bio-based CE.

The EU Action Plan for the Circular Economy (EC 2015) highlighted the role of the regions in taking action to promote the CE. Also, the Interreg Europe program emphasises the regions to exchange and learning from each other. One successful example of the BIOREGIO project is how the good practice of the Päijät-Häme region's CE strategy inspired the Spanish region of Castilla-La Manca to initiate a CE law in 2021, as the first in any region in the country (Frontaura Sánches Mayoral & Vanhamäki 2020; Castilla-La Mancha 2021). This example shows how an interregional project can support policy changes in other regions.

In addition to other achievements, BIOREGIO project partners and their stakeholders have increased their knowledge capacity on the topic of bio-based circular economy through interregional cooperation and information exchange. Based on the capacity survey conducted at the end of Phase 1, approximately 90 people increased their professional capacity thanks to their participation in BIOREGIO interregional cooperation and 49 policy-learning events.

BIOREGIO was granted an extension until the end of 2022 where the focus is on elevating regional development through new projects and renewed policies. The key theme is dedicated to the exchange of information on COVID-19 and bioeconomy measures taken in the project partners' regions. A special focus is devoted to small- and medium-sized enterprises (SMEs), as they are essential for local bio-based economy development. The project's additional activities encourage public authorities to prepare calls for recovery measures targeting bio-based circular economies and assisting stakeholders, particularly SMEs, in applying for funding. These activities include exchanging experience and information on available technologies, inspiring solutions (new good practices), and continuing interregional cooperation between BIOREGIO partners. The additional activities may also assist the authorities in advancing the new programme period of the European Regional Development Fund (ERDF) 2021–2027 in terms of new projects to boost regional bio-based circular economies, as well as to overcome the impact of the COVID-19 crisis. So far, the BIOREGIO partners have submitted three new good practices linked to the additional activities that could inspire the Interreg Europe community to solve regional challenges (Interreg Europe 2022b).

4. Conclusion

In a changing world with an increasing demand for local energy supply and closing nutrition cycles, developing bio-based CEs is even more important than before. By sharing experiences and improving regional policies to better support new bio-based solutions and technologies, the BIOREGIO project has enabled development in all participating regions at the policy level and in practice. For example, the explained case, where the Päijät-Häme region's CE strategy inspired Castilla-La Mancha is a successful example of an exchange that would not have happened without the support of the project. This kind of policy change will affect the whole region in the coming years and decades.

Solutions to our challenges may already exist. Thanks to projects, such as BIOREGIO, where actors from various sectors and EU regions share and exchange their knowledge and concrete examples, can speed up the transition towards bio-based circular economy.

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