Citizen participation in public infrastructure digital common twins

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Abstract:

Public infrastructure digital common twins are a new type of organization that can play an integral part in the smart city. They are organizations that are collectively owned by citizens, making use of digital twin technologies to facilitate collective decision-making on smart city issues. To make this development a success, there is a high need for citizen involvement in these organizations as the public infrastructure digital commons must be run and managed by citizens and communities themselves. Therefore, this research considered the adoption challenges of citizens participating in and utilizing these digital platforms. The research did so by first, conducting exploratory interviews with citizens of all kinds of demographics, after which the challenges uncovered in these interviews were used to find solutions. By making use of the Unified Theory of Acceptance and Use of Technology (UTAUT), combined with the dynamic capabilities of the resource-based-view, this research explains the citizen adoption challenges and organizational solutions. These solutions were found through interviews with experts from public infrastructure digital common twins and these solutions laid the foundation for a conceptual model that was formed to show the relationship between the different dimensions of citizen adoption. This model includes organizational capabilities, which influence citizen contributory participation and citizen utilization of the platform, which allows for the social and inclusive impact of the organization. This model is further discussed in this research, providing insights into the dimensions and giving context to the meaning of the framework. The contributions of this research are to the literature of digital commons by integrating their participatory nature into the UTAUT framework. It extends the resource-based view by researching it in the context of democratic collectively owned digital commons and it contributes to digital twin literature by demonstrating its functioning in citizen owned organizations. To finish this thesis, outlined are the recommendations for practice and academics, and lastly the conclusion.

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1. Introduction

Digital technologies have advanced significantly, continuously increasing their capabilities each year. This advancement has allowed for a stark increase in information access in the world and this digital transformation has become a vital part of life for people and organizations around the globe (Trier et al., 2023). This digital transformation has brought to life the concept of digital commons, which are shared virtual platforms that focus on common ownership and governance of information and digital resources, to share knowledge and run on participatory governance (Bühler et al., 2023). Digital commons can also be combined with digital twins, which are technologies that link the digital world to the physical environment through a connected data linkage, with the digital twin being a digital representation of a physical asset (Van Der Valk et al., 2021). The combination of these technologies could potentially make significant contributions to the development of smart cities. However, the rise of these platforms also brought with them challenges that must be navigated by organizations, users, academics, and society together. One of these key challenges is citizen adoption, which looks at whether the citizens will use the technology. This challenge is vital, particularly in the smart city, since without individuals using the technology the development of smart cities will fail (Baldi et al., 2022). Besides using technology, this research considers citizen's participation to contribute to the technology and the organizations, as citizen participation in operations and maintenance is essential to digital commons (De Rosnay & Stalder, 2020). Furthermore, citizen participation and use are of importance due to the common ownership of resources of digital commons (Bühler et al., 2023), which in the smart city would refer to the citizens. Meanwhile, despite these reasons showing why citizen adoption is highly relevant for the public infrastructure digital common, the adoption challenges faced in this context have not been researched before. This challenge therefore required to be expanded upon in this time when smart cities are becoming more common due to their ability to address issues regarding sustainability, their ability to improve economic growth and their overall ability to increase the quality of life of citizens (Gracias et al., 2023) and a time where there is a substantial interest in the use of city digital twins in collaborating between local governments and citizens (Adade & De Vries, 2024). Therefore, the reason why this citizen adoption challenge is relevant is due to the differing nature with citizen contributory participation, which contrasts with technology acceptance where users are only utilizing the technology and not contributing to it, necessitating research focused on this problem. Looking at the background of this research, the research comes from a research

problem presented by a company in the energy sector, with the aim of creating a framework that focuses on the citizen adoption of digital commons, with a special lens for public infrastructure digital common twins. Digital public infrastructure here refers to “digital systems that are secure and interoperable and that can support the inclusive delivery of and access to public and private services across society” (OECD, 2024). Examples of public infrastructure digital common twin platforms in the research are one that informs stakeholders that live near airports on air traffic, noise pollution and regulation to empower citizens to hold airlines and airports accountable. Another example is the use of digital twins to spread real-time travel information on traffic and carbon emissions to citizens. While two other organizations were energy commons that use their platform to provide energy to citizens in the common. To research these challenges, the guiding research question throughout the research was "What key citizen adoption challenges arise from using digital commons in public infrastructure digital twin, and how can they be addressed?”. To answer the question eight citizens and eight experts were interviewed through semi-structured interviews, after which a qualitative thematic analysis was employed. The frameworks used were the Unified Theory of Acceptance and Use of Technology (UTAUT) and the resource-based view with its dynamic capabilities. The research contributes to digital commons by researching real use cases and providing a clear overview of citizen adoption challenges and solutions. Meanwhile the research contributes to UTAUT through linking it to contributory participation, where citizens take an active role in the maintenance and development of technology. It also contributes to the resource-based view and its dynamic capabilities because it considers the framework in a unique governance form, which includes democratic organizational governance. The contribution to smart-city digital twins comes from researching it in direct control of citizens, instead of under the control of traditional organizations and public institutions. This thesis will first present the background and research gap and then expand the research question. Afterwards, the literature background is presented, followed by the theoretical frameworks and methodology. Next are the results and the discussion, after which the limitations and future research directions are mentioned, which are followed by the conclusion.

2. Background research gap

There are also some research gaps in the literature background to discuss as this research is part of a young research field that is only coming up recently with the rise of smart cities.

Looking at the background surrounding this research, there are some research gaps that this study is filling. Firstly, many articles focus on the perspective of the government in implementing smart city developments. Articles such as (Dembski et al., 2020) have a high focus on how urban digital twins can be implemented considering the citizen perspective, however, this case study was not conducted through the lens of digital commons, therefore not allowing for citizens to participate in the governance process. Meanwhile, articles such as White et al. (2021) examine smart cities from the perspective of how digital twins in the smart city can improve the lives of citizens. However, this article again does not involve citizens in the use and governance of these smart city technologies. Another article that looks at urban commons is Long et al. (2023); however, this article considers the use of decentralized commonly governed Distributed Ledger Technologies to increase the transparency of data in the urban environment. The article has a citizen-centered look at the possibilities that commons have, but it does not delve into what makes citizens willing to use them and does not discuss the concept of digital twins and therefore differs from this thesis. Other articles disregard to even consider the digital city twin from the citizen perspective, where articles such as Yaqoob et al. (2023) focus on how the digital twin can expand on the metaverse and what different applications this could possibly have for organizations in the metaverse context. However specifically with public infrastructure digital common twins, citizens can under no circumstances be disregarded, as digital commons are collectively owned, governed and controlled by citizens (Bühler et al., 2023). This means that technology acceptance research in the literature would have had to address the acceptance of participatory technology development from citizens, however this was not present. Instead, existing technology acceptance literature is focused on users' acceptance of technology as it is given to them, instead of focusing on the acceptance of technology in contexts where acceptance requires further effort into the development of the accepted technology. This can be seen most clearly in technology acceptance literature, such as Davis (1989), which considers technology acceptance as simply the usage of systems dependent on what it brings to their job performance through 'perceived usefulness' and how difficult it is to use through 'perceived ease of use'. Later technology acceptance models, that add on to the field, do mention user participation in technology acceptance, although this differs from the user participation in digital commons. The difference lies in the fact that user participation is framed in the context of understanding top-management perspectives, aiming to help employees see the relevance of the adoption, while the user participation also just occurs during the pre-implementation stage (Venkatesh & Bala, 2008). Therefore, the research addresses two gaps, firstly the gap on

theory on digital commons and its unique citizen governance, as it shows that there is a lack of research on digital commons that focusses on their relationship with user adoption. Rather the research focusses on organizational functioning of digital commons or wider. However, as mentioned this citizen participatory governance differs from conventional technology adoption providing unique contexts. Secondly, the digital twin perspective is not yet combined with digital commons in the research. However, this link is relevant as these types of organizations are already active within the European Union as can be seen in this research, as well as the shown link between digital twins and urban matters. To further stress the importance of the problem researched, the European Union has its own strategy that focusses on leveraging digital twin technologies for citizen participation where citizens are empowered to make decisions in projects concerning them (European Commission, n.d.).

3. Research question

Based on the identified background and the research gaps, the research question was formulated. The research question of this thesis is “What key citizen adoption challenges arise from using digital commons in public infrastructure digital twins, and how can they be addressed?”. The research question guided the research throughout the process and ensured that the research remained focused on its purpose. Before going further, the question requires some explanation to ensure that it is clear what the research goal of this thesis was. Starting by quickly re-introducing digital commons, which refer to shared virtual platforms that focus on collective ownership and management of information and digital resources, operating through participatory governance (Bühler et al., 2023). Meanwhile digital twins connect the digital space to the physical world using data linkages, where each digital twin is a digital replica of a physical asset (Van Der Valk et al., 2021). Then considering the research question, firstly, this research focusses on citizen adoption, which was done to uncover challenges and important factors regarding citizens being hesitant towards the use of and participation in digital public infrastructure common twins. This was done to give practical recommendations towards these challenges in the world of digital common technology acceptance from an expert perspective. Also important to note is that with citizen adoption, the focus of the research is on the cognitive perceptions of citizens through their interviews on what they believe to be the biggest challenges, while the Unified Theory of Acceptance and Use of Technology (UTAUT) was used as the theoretical framework. Using UTAUT allowed for this research to be centered within the academic world of technology acceptance, while discerning itself by using this framework in the context of this new and upcoming technology which

includes citizen contributory participation. Secondly, it is important to clarify what addressing these challenges means, which comes from the understanding of how digital commons are governed. With digital commons being self-governed by the communities that use them, these recommendations will be aimed at those participating in the governance process of the digital commons. This is done by considering the capabilities of these organizations. The theoretical framework used was the resource-based view of the organization, where these citizen adoption challenges can be addressed by organizations through the use of their capabilities and resources (Barney, 1991). The aim of the question was in the context of the social benefits, where addressing these challenges provides benefits for society, instead of just organizational performance. This research, therefore, also touches on corporate social responsibility, where corporations are involved in activities to be more socially responsible regarding environmental and social considerations (Gillan et al., 2021).

4. Literature background

Considering the different elements of the topic of this research, all important elements are given their own more in-depth explanation, to give a better understanding of the technologies, their relationships and what makes them unique.

4.1 Digital Twins

The concept of digital twins entails a wider set of definitions than can be explained in one sentence due to the different levels of data connectivity that exist for digital twins; therefore, it is important to explain more in-depth. Digital twins refer in the simplest terms to digital representations of physical assets that have a data connection. The key aspect of digital twins is that they are technologies that link the digital world to the physical environment through data linkage (Van Der Valk et al., 2021). The goal of digital twins is to enable users to manage physical assets throughout their life cycle through digital means (Meske et al., 2021). In essence, digital twins continuously transform based on data of the physical object to improve the representation of the physical object (Meske et al., 2021). They contain three parts: “physical product, virtual product, and connected data that tie the physical and virtual product” (Tao et al. 2018, quoted by Van Der Valk et al., 2021). This is similar to digital models and digital shadows; however, the difference is in the direction of data as they lack automatic and real-time information feedback that digital twins give back (Wurm et al., 2023), as is illustrated in figure 1 below.

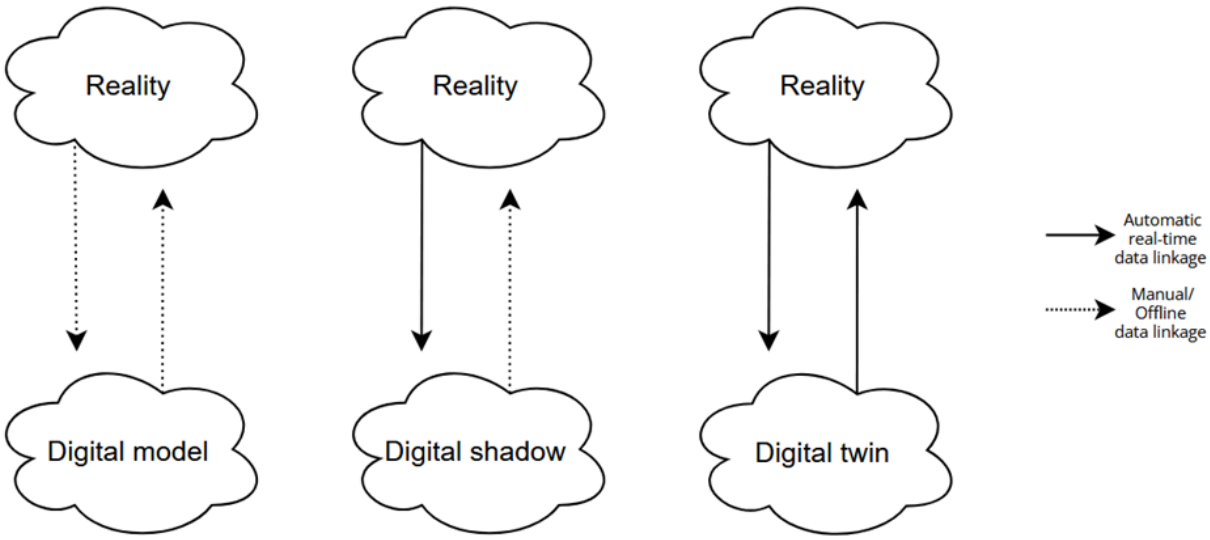

Figure 1: Model demonstrating the difference between the concepts of digital models, digital shadows and digital twins. Adapted from Van Der Aalst et al. (2021).

Digital twins have different applications; the first one is for simulation purposes, where the digital twins reproduce the behavior of physical products. The second one is monitoring, where the real-time status is considered of the physical object based on the relay of live feedback and thirdly is the control purpose which is when the digital twin has active control over the physical object and can make adjustments based on the current information it possesses (Enders and Hoßbach., 2019). Digital twins differ in technological capability, with Van Der Valk et al. (2021) finding five archetypes ranging from the digital twin types with the least to the most capabilities. Archetype 1, called the "Basic Digital Twin", is a digital twin that is a virtual construct and has a bi-directional data stream between the physical asset and the digital counterpart. However, this archetype only extends the digital twin by a human-machine interface, which enables users to access the output data of the digital twin. Archetype 2 is enriched with semi-manual processes to obtain data with supplementary systems, while archetype 3 features autonomous control over another machine, while also still allowing human intervention. Archetype 4 has enhanced full autonomous control over another system without human intervention, while improving on data processing systems. Archetype 5, called the "Exhaustive Twin, is the most capable as it acquires and processes data and exercises control over the physical counterpart. It also allows users to intervene and add data to the database. Overall, the smart city digital twins in this research are more similar to basic digital twins, as explained in the following paragraph.

4.1.2 Background of digital public infrastructure digital twins

Looking into public infrastructure digital twins is also of interest, since the term digital twin is often used in the smart city when dealing with technologies similar to digital shadows, as these technologies often do not possess a bi-directional data process. Examples of public infrastructure digital twins include a 3D simulation for solar power, where the ideal placement for solar panels is shown through color coding or a simulation of what would happen in case of a flood and what places of the city would face what risks during a flood (Living Digital Twin, n.d.). Examples of bigger use cases include the digital twin of New South Wales province in Australia, where the tool models the urban environment while providing information to users such as live transport data, utility maps, infrastructure and properties (CSIRO, n.d.). Singapore also created a digital twin called “Virtual Singapore”, which includes a digital copy of the country with real-time data on aspects such as buildings, infrastructure, population movement and the environment (Observatory of Public Sector Innovation, 2024). The maturity stage of this technology is however still young. As found by Ferré-Bigorra et al. (2022), of the twenty-two urban digital twins in urban management they were able to find, only four were in operation, while the others were still merely prototypes or still under development.

4.2 Digital Commons

The concept of digital commons is highly relevant as well. Digital commons can be defined as “a shared virtual realm where digital knowledge, information, and assets are managed collectively by a community”, where the idea is that users have access to the information and the ability to contribute to these resources and communal democratic governance is encouraged (Bühler et al., 2023). However, there are also issues with digital commons that must be overcome to harness its potential. Bühler et al. (2023) found four of these issues, starting with regulatory barriers where institutional factors do not support digital commons, causing legal issues. The second issue is that smaller communities have a more difficult time implementing digital governance structures and models due to resource constraints. Thirdly is the issue of unequal access which means that not all groups have equal opportunity to participate in the digital commons, and lastly the securing of data privacy in digital commons requires robust governance frameworks and technical solutions which can be difficult to solve. Another factor of digital commons is that it takes away the information control of private businesses and gives it to people, researchers and companies alike, where all actors can choose what information they are willing to reveal which in turn benefits society through

research and gives back the power to the citizens (Hafen, 2019). The link between digital commons and the different spheres of society is also relevant (Fuchs, 2021), where these dimensions are all linked together. Firstly, is the nature dimension, where the digital commons need to be based on sustainable practices to form the physical foundation of the common. Secondly, the economic foundation of the digital common must involve the common ownership of the digital asset, while the digital common is non-profit. Thirdly comes the political dimension that underscores the importance of the collective democratic governance that encourages participation and lastly is the cultural dimension that points to the need for diversity and respect in the use of digital commons (Fuchs, 2021). Digital commons are also considered to be a good fit for infrastructure, including by the governments of the Netherlands, France, Estonia, and Germany, as they provide the opportunity to create a digital environment that aligns with European values such as privacy, transparency and equality (NL Digital Government, 2024).

4.3 Challenges of citizen adoption of smart-city technology

Looking into the background of citizen adoption of technology, multiple factors are relevant. They are also summarized in table 1 below. Firstly, regarding the advancement of smart cities, many citizens are not capable of participating in these smart cities due to a lack of technological skill and awareness issues, even though citizen engagement is highly important to smart services (Shin et al., 2021). Citizens also need to see the value of smart technologies, with research showing factors such as sustainability, benefits, ease, value and self-efficacy to be of importance for citizens to use smart city technologies (Baldi et al., 2022). These factors also link to the model of Shin et al. (2021), which considers the access stages of motivational access, material access, skill access, and usage access. They consider the digital divide where there is a disparity in access between various groups of people, besides their perceived necessity of technologies. For the demographics factors this research found that most frequently this gap is due to age, education and geographic location in the usage of new technologies. Also, their user-friendliness is a significant barrier, specifically for groups that have lower digital skills (Morte-Nadal & Esteban-Navarro, 2025). Citizen technology adoption also includes barriers such as trust, security and transparency with accepting e-government technology, where the level of trust in earlier stages has a lasting effect on the trust levels later (Colesca, 2009). There are many factors that the article outlined as relevant factors to trust in e-government, with greater perceived trust in technology and organizations, the quality and utility of e-Government services, their internet experience, and citizen's

tendency to trust all positively contributing to trust in e-government. Meanwhile, the factors of age and privacy concerns harmed the trust in e-government. Another research found that internet trust issues are relevant to citizen adoption, where trust in general institutions that facilitate the use of digital public infrastructure is needed (Li, 2021). The implementation of smart city technologies is also hampered by technical challenges, social and cultural challenges and financial and legal challenges (Gracias et al., 2023). For technical challenges, the issue comes from a lack of standardization of data integration and the lack of interoperability between smart systems. Financial and legal challenges come from the need for long-term investment, which can be difficult for most projects where there is a limited budget pool to get funding from, as well as the legal issues with regulation regarding data use. Lastly, the social and cultural challenges are also a big challenge due to the resistance to change seen in citizens and their concerns regarding data privacy (Gracias et al., 2023). The need for assistance is also an issue, where the inability to contact an employee to assist with the use of a digital public service leads to a feeling of helplessness from users (Morte-Nadal & Esteban-Navarro, 2025). Trier et al. (2023) also finds that group discrimination is an issue that must be considered when dealing with digital participation. Lastly, the issue of the temporary nature of pilot projects has to be considered where communities that have been involved in the pilot project lose access to the technology, which leads to communities feeling used (Khutsishvili et al., 2024).

Table 1: Summary of citizen adoption challenges in the literature

Challenge:	Short explanation:
Digital literacy challenge	Citizens do not possess the skills to participate in the smart city (Shin et al., 2021)
Perceived value	Citizens must see the value that the smart city provides for them (Baldi et al., 2022)
Access inequality	Motivational, material, skill, and usage access gaps (Shin et al., 2021)
Privacy challenge	Privacy is important to people, so this needs to be guaranteed (Gracias et al., 2023)
Technical challenges	Different technologies put together do not work together smoothly (Gracias et al., 2023)
Assistance challenge	Users feel helpless if employees don't help them (Morte-Nadal & Esteban-Navarro, 2025)
Discrimination	Group discrimination has a significant effect on digital participation (Trier et al., 2023)
User friendliness	Platform design needs to be convenient for users (Morte-Nadal & Esteban-Navarro, 2025)
Pilot project trust issues	Losing access after pilot-project makes users feel exploited (Khutsishvili et al., 2024)

Trust issues	Citizen trust in institutions influences technology adoption (Colesca, 2009)
Change resistance	Resistance to change is a barrier to people adopting new technology (Gracias et al., 2023)
Institutional challenges	Long-term investment challenges and regulations problems (Gracias et al., 2023)

5. Theoretical framework

For this research, two different theoretical frameworks were used. For the explanation of the citizen adoption challenges of the public infrastructure digital common twins, Unified Theory of Acceptance and Use of Technology (UTAUT) model was used. Then, based on the citizen adoption challenges, the use of the Resource-Based View explains how organizations address these challenges, with a focus on their dynamic capabilities.

5.1 Unified Theory of Acceptance and Use of Technology

When dealing with the citizen adoption of public infrastructure digital common twins, it was important to make use of a robust technology acceptance framework that could provide a solid foundation for the explanation of the citizen adoption challenges. For this framework to be suitable, it was also pertinent that the framework had been validated. Therefore, the "Unified Theory of Acceptance and Use of Technology" was used. The Unified Theory of Acceptance and Use of Technology (Venkatesh et al., 2003), abbreviated as UTAUT, is a technology acceptance model that aimed to consolidate the scientific views of user acceptance of technology within a single model. The model makes use of the variables of "Performance expectancy", "Effort Expectancy", "Social Influence" and "Facilitating Conditions" to explain the behavioral intention of the user to adopt the technology. In this model performance expectancy refers to whether the user would believe that the technology will help them in their performance. The second variable effort expectancy is here defined as the ease of use that the person expects of using the technology. Social influence is the third variable, and it looks at the level of social pressure that is on a person where they believe there is an expectation from others that they will make use of the technology. The last variable of facilitating conditions looks at whether the variables surrounding the technology are favorable through support and the availability of resources. The variables of "Performance expectancy", "Effort Expectancy", "Social Influence" have a different effect on the use of the technology

than the “Facilitating Conditions”. This is because in the model “Behavioral intention” serves as a mediator variable between the first three variables and the end variable of “Use Behaviour”, while the variable of “Facilitating Conditions” directly influences the variable “Use Behaviour” Within the model there are also four moderator variables, which are “Age”, “Gender”, “Experience” which refers to prior experience with the system and “Voluntariness of use”.

The model provides a clear and proven framework for technology acceptance which, through the use of only four variables, is also easy to understand. Another reason why the model was suitable is because the challenges found in the initial literature review, which are challenges more specific to the technologies such as digital commons and in the context of the smart city, are also linkable to the variables of the UTAUT model. The social influence factor also made this model specifically interesting to use, since technology acceptance will happen in a societal setting where these effects are of interest to understand and research. However, this research also puts the UTAUT framework in a novel context due to the nature of technology acceptance of digital commons. Digital commons are, as mentioned previously, based on collective governance (Bühler et al., 2023), which means that technology acceptance also encompasses the aspect of accepting the responsibility of participating within the governance, which UTAUT has never been used for. In the past UTAUT, however, already has been used in a wide range of other settings as found by Venkatesh et al. (2016), including physicians accepting speech recognition technology, citizens accepting e-government and political social media channels, students accepting tablets for learning, teachers accepting e-learning platforms, consumers accepting social media and smartphone apps and academics’ acceptance of social media for researching.

5.2 Resource-Based View

Within the research the organizations also provided solutions to the citizen adoption challenges. To explain how organizations solve these challenges, the resource-based view (Barney, 1991) was employed as an analytical framework for the strategies of organizations and to understand the nature of their interplay. The resource-based view (Barney, 1991) is a view of organizations that explains the functioning of firms through their possession of capabilities and resources that give them a competitive advantage. To gain a competitive advantage, resources should be valuable, rare, inimitable, and non-substitutable, and there

must be an organization in place that can absorb and make use of these resources (Kraaijenbrink et al., 2009). One of the defining characteristics of the resource-based view is the inward view where the functioning of the firm is dependent on the capabilities of the organization rather than the industrywide capabilities. Capabilities are also considered to be immobile in this view, making it difficult to acquire these capabilities for your organization, meaning that if an organization does not have the capability for specific strategies, it will not be able to implement them in the short term (Kraaijenbrink et al., 2009). Central to the resource-based view is the belief that organizations are bundles of resources scattered heterogeneously throughout the organization. To fully explain the advantages organizations get in the resource-based-view, the use of dynamic capabilities is often made (Eisenhardt & Martin, 2000). The dynamic capabilities, as described by Teece et al. (1997), are competencies that can renew themselves based on changing environments and are based on strategic management abilities. Within the article of Eisenhardt and Martin (2000), dynamic capabilities are seen as "organizational and strategic routines by which firms achieve new resource configurations as markets emerge, collide, split, evolve, and die". This shows that dynamic capabilities build upon the resource-based view by providing an explanation to how organizations can utilize and reconfigure their resources. However, challenges arise for the capability-based lens of organizations with the resource-based view since with its inward-looking perspective, organizations are more dependent on their history and specifically their evolutionary path of capabilities through past sets of rules and routines set by management (Mahoney & Pandian, 1992). The resource-based view, although created in the context of for-profit firms, is also applicable to organizations that are not looking to be profitable, such as public infrastructure digital commons. There are three main reasons that the resource-based view is relevant to non-profit firms, as posed by Akingbola (2013). This is because firstly the decision-making and resource allocation as described by the resource-based view are also valid and important for non-profit firms. Secondly, the idea that capabilities and resources are socially complex in the resource-based view fits as this paradigm is also present within social economy organizations. Lastly, the resource-based view can be looked at from the human resource perspective, which is of huge importance to social economic organizations. Thus, considering these reasons, the resource-based view lays an apt foundation for non-profit firms functioning. Therefore, considering the digital common is non-profit, this theoretical framework gives the ability to explain how public infrastructure digital commons can solve the citizen adoption challenges.

6. Methodology

6.1 Research instrument

This research was conducted making use of semi-structured interviews with citizens and public infrastructure digital common twin experts, totaling 16 interviewees combined. The research employed a qualitative analysis due to the desire to gain a deeper understanding of the underlying factors of citizen adoption that are of relevance to the citizen's adoption of digital commons. This was particularly of interest due to the not easy to quantify and complex aspect of human interaction with technology and its ethicality. These considerations made a qualitative study a good fit, as this methodology allowed for a more interpretative approach (Cypress, 2015). To avoid irrational generalizations in this research, the level of analysis must be made clear as well (Makadok et al., 2018). This thesis chose to put its focus on the perceived challenges of citizens to use and participate in digital commons in the digital public infrastructure digital twin context on a citizen analysis level and for the solutions on the organizational governance level. This research made use of qualitative semi-structured interviews to assess the key elements needed to ensure the citizen adoption of public infrastructure digital commons. After the first round of interviews there was a second round of interviews hosted with people working for organizations involved with the digital public infrastructure digital common twins to understand the organizational context of dealing with the challenges from the citizen interviews. This second round of interviews was based on the results of the first round of interviews. Through a qualitative analysis, this research sought to gain a deep understanding of the different elements that play a role in citizen adoption of public infrastructure digital commons, linking the literature and interviews together, while also providing a framework for how organizations deal with these citizen adoption challenges.

6.2 Sample

The interviewees were firstly eight citizens and then secondly eight experts involved in the public infrastructure digital twins. The experts were needed for their deep understanding of digital commons combined with their experience in the governance of these digital common twins and the citizen adoption challenges. Citizens were required to gain a deeper understanding of the challenges of citizen adoption and their unique insights into their willingness to use these public infrastructure digital twins. The citizens interviewed were both men and women and encompassed different age groups and different education levels. This

choice was made to make the sample as representative as possible for the demographics of general society. The interviews made use of purposive sampling due to the ability of this method to ensure that the interviews made use of participants with the characteristics that are needed to assist the research and ensure participants are well-informed (Etikan, 2016). This was specifically beneficial regarding the industry experts, as they were difficult to find, and it was important that they fit the criteria. The research conducted eight semi-structured interviews in the first round with citizens, who are of different age groups, gender and educational backgrounds. After the citizen interviews, the research was followed with seven interviews with eight industry experts, with one double interview with experts from the same organization. These industry experts were part of organizations engaged in public infrastructure digital commons with the digital twin perspective, giving them insights into organizational methods to deal with the citizen adoption challenges. Examples of organizations from the sample are one that informs citizens living near airports about air traffic, noise pollution and other regulations, while another gives real-time traffic information to lower carbon emissions. There was also an organization that measured air quality at key locations in the community, such as children's playgrounds. Two other organizations are focusing on energy, where they are supplying their own community with energy through the common. The interviews with both groups were conducted online, unless otherwise specifically requested by the interviewees. Overall, this method ensured that there were enough different perspectives heard, and it gave the opportunity for experts to directly give insights regarding the earlier citizen interviews.

6.3 Data collection

As per the custom of research, an initial literature review was conducted to scope the research field regarding digital commons to create the theoretical background and to gain an understanding of the hurdles and barriers already that exist regarding the citizen adoption of digital commons. For this preparatory phase, a scoping type of review was used as described by Aguinis et al. (2020), which meant that the literature review was focused on providing the initial indication of the scope of the literature and tried to find gaps that needed to be further researched. The focus for this type of literature review lies with the breadth of the literature instead of going for an in-depth analysis. After a baseline understanding was achieved, an exploratory interview guide was created for the citizen interviews. All citizen interviewees did receive an explanation of what the new technology entailed before the interview, and examples were available to give the citizens a clearer view of the technology discussed. This

data collection process of the interviews in this stage was done through the recording of the interviews. These recordings were afterwards turned into raw anonymized transcripts of the interviews, which were then used as the data set. The interviews were conducted online unless otherwise requested, both for the first round of interviews with the citizens and the second-round experts. To ensure ethical compliance during the data collection, all participants were asked to sign a consent form and were given the option to opt out of the research at any time if they are no longer comfortable with their data being used. The process was also submitted for ethical approval to the ethics committee before the start of the data collection to ensure that necessary changes could still be made if necessary.

6.4 Data analysis

After all the interviews were conducted, the data was analyzed to find the patterns between the interviews and to group the common dimensions. This was done by conducting a thematic analysis following the recommendations of Braun & Clarke (2006). This method follows multiple steps to ensure a systematic approach to the thematic analysis. The first step is the step of becoming familiar with the data by reading it multiple times and transcribing all verbal data, also anonymizing the data. Then step two was to make an early list with codes and write down why these early codes were chosen. Specifically, since the codes for this research are data driven, it was important to think deeply about what parts of the data are of interest early on. This method also required systematic working to ensure that all data gets the same amount of attention. Then step three of this method was to group the codes to create themes, for which similar codes were grouped together. At the end of step three there were a number of potential themes that were reviewed in the next step again. The creation of the codes and themes was done through the recommendations from Gioia et al. (2012) where it was important that the first order concepts stayed true to the interviewee's intent, which then for the thematic analysis was combined for the second step of creating overarching themes. These themes all fall under aggregate dimensions, to which later the analysis of the expert interviews was also linked. In the fourth step the themes were decided on by critically deciding which were relevant. The themes that were formed early on but were not actually of relevance were dropped. This step was also done more than once to see if anything new came up, and when new insights were no longer found with the repetition of the step, the method moved on to step five. In step five there was the focus on defining the themes as precisely as possible and making sure that the themes really encompass what is being claimed, as there is a risk of it going too wide or making it too complex. This was also done more than once to ensure they

were defined as accurate as possible. The last step was to write up the thematic analysis into a clear account that is truly based on what the data says. In this step it was also important to make use of examples from the themes in the thesis to ensure that the argument is clear to the reader. In this final stage, the framework for the governance of digital commons to ensure citizen adoption was created.

6.5 Coding process

During the coding process as mentioned above, the process was structured according to Gioia et al. (2012). After the interviews were conducted, they were fully transcribed and anonymized. This process of cleaning up the transcripts was done by listening back to the whole recording while reading the transcript to ensure that no mistakes were made in the transcript. Once the transcript was cleaned and ready for analysis, the initial coding began, with each interview being read through twice to find all relevant in-vivo codes. After all the transcripts were coded, the next step began, creating the themes of which many groupings were found. Going through the step of creating the order themes for the second time, two themes were dropped due to lack of data to truly support them. All the themes were then worked out in text to better understand their meaning and to gain a clearer view of which ones to group into aggregate dimensions. When this part of the process was finished, aggregate dimensions were created, where the groupings were made on similar origins and deeper similarities between the themes. The second round of interviews had the questions in the interview guide already structured based on the dimensions and themes of the first interview round. This meant the coding process was facilitated by the codes on the challenges being grouped. After this point, the coding process was the same as in the first coding round, where a structured look was used to find patterns and group codes together based on their similarities. After both analyses were complete, the data was analyzed one more time, to check the accuracy of the findings and to see if adjustments still had to be made.

7. Results

The analysis of the citizen interviews led to the discovery of five citizen adoption dimensions regarding the research question of “What key citizen adoption challenges arise from using digital commons in public infrastructure digital twins, and how can they be addressed?”.

These factors, which were uncovered through a thematic analysis of the interview transcripts, require some deeper explanations to better understand what these challenges to citizen adoption entail. To give deeper insights into the five discovered dimensions, they are all explained through the deeper themes they cover. All these challenges were uncovered by multiple interviewees, and they were recurring dimensions throughout the analysis process, making all of them important to consider. The aggregate dimensions are organizational capabilities, user platform utilization, citizen contributory participation, social and inclusive impact, and data management. The second part of the results answers the question of how these challenges can be addressed. The solutions are classified within the same dimensions opposite to the challenges, meaning that each challenge dimension has its own counterpart describing the results from the analysis of the expert interviews. The organizations interviewed were all working on sustainable living communities and sustainable traveling outcomes through the empowerment of citizens, making use of digital twins. Table 2 provides an overview of the sample of the citizens interviewed, while table 3 shows the sample of the experts. Table 4 provides the individual challenges and their solutions, meanwhile the full Gioia data structure can also be found following the different tables in figure 2.

Table 2: Citizen interviewees

Interviewee:	Gender:	Age range:
C1	Male	56-65
C2	Male	18-25
C3	Female	66+
C4	Male	26-35
C5	Male	56-65
C6	Female	46-55
C7	Female	26-35
C8	Female	18-25

Table 3: Expert interviewees

Interviewee:	Gender:	Age range:	Role:
E1	Female	46-55	Business analyst
E2	Male	18-25	Managing director
E3	Male	66+	Founder
E4	Male	46-55	Project Lead
E5	Male	66+	Senior manager
E6	Female	26-35	Legal advisor
E7	Male	56-65	Senior Consultant
E8	Male	56-65	CEO

Table 4: Results with challenges and solutions

Challenges:	Solutions:
Volunteer capabilities	Recruitment process; Role-specific guidelines; Compensation structures; Workshop training sessions; Skill-based volunteer gatekeeping; Partnerships to provide assistance to volunteers
Digital Common Structure	Have a code of practice for rights and responsibilities; Executive and oversight board; Controlling and monitoring processes; Map out and set up a partner collaboration network
Conflict Resolution	Using proven and pre-defined conflict resolution processes (CEDR); Partner with local partners for third-party judgements and decisions
Transparency	Sharing all relevant information on the platform; Have a code of practice for rights and responsibilities
Ease of use	Getting a UI/UX designer; You need to get API developers; Prototyping with different designs; We research user-preferences and literature
Understandability of information	Removing complicated graphics and simplify them; Identify different stakeholder information needs
Visual Appeal	Gamify the interface; Getting UI/UX designers; Research with focus groups and considering other cultures
Effective assistance	Have different levels of support based on type of request; Calling leadership directly for questions; Assistance through a commission with relevant stakeholders; Giving Webinars; Support directly from familiar people in community
Convincing users to give feedback	Choosing the correct outreach channels; Community based voucher programs; Outreach with in-person events; Social media presence; Targeted stakeholder engagement; Leveraging personal networks
Feedback processing	Combining feedback channels; Use analytics to classify feedback; Use participatory design methods; Voting on suggestions; Visualizing feedback impact
Participation impact	Engage stakeholders to adapt their input to relevance for their community; Storytelling on how it benefits the citizen personally; Provide personal impact metrics
Platform performance	Let citizens set the performance metrics for the community; Creating systems with user purpose in mind; Use metrics that are interesting to wide range of stakeholders; Ensure performance through using certified qualification; Show impact of platform through objective professional measurements
Accessibility	Leveraging technology to empower the those that need it (E.g. Text-to-voice); Deliver solutions based on cultural preference and disabilities; Bottom-up strategies
Importance of communality	We host a BBQ in the community; In our open sessions at the community center people come just to be there; Creating fun and social settings to get to know each other; Citizens can create their own initiatives
Privacy Desire	"Cartoonify" privacy explanations for simplicity; Offer one-on-one meetings to explain; Communicate the used security systems and protocols; Creating clearly defined consent forms; Conveying care for privacy in platform
Data Security	Data collection minimization; Using state-of-the-art security systems; Testing security systems and protocol; GDPR and legal Compliance; Make data collection dependent on citizen's way of using the platform

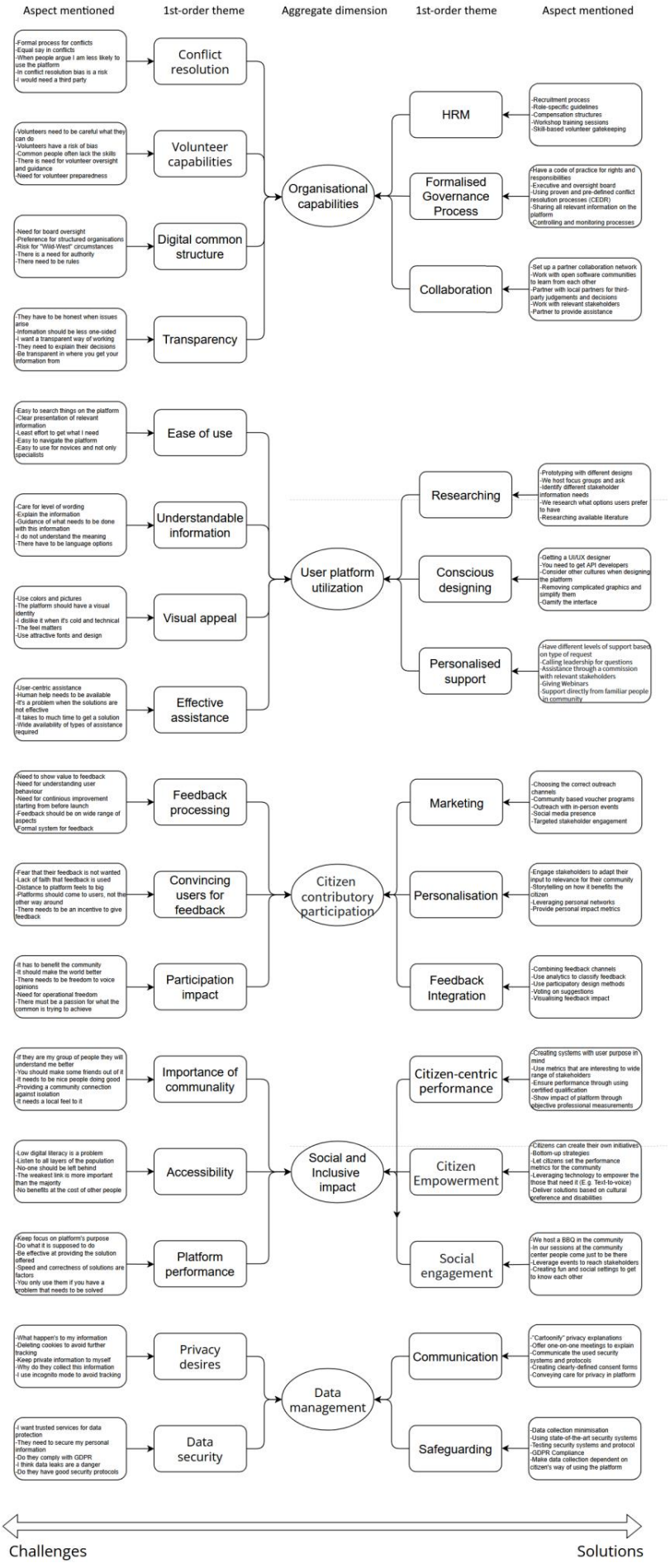

Figure 2: Gioia data structure

7.1 Organizational capabilities challenges

The first overarching dimension was the organizational capabilities, which form the basis of the public infrastructure digital common twins. Looking at challenges in this dimension, citizens felt that aspects such as the volunteer capabilities, the structural professionalism, the conflict resolution, and the organizational transparency were important for them to utilize these platforms and contribute to their development.

7.1.1 Volunteer capabilities

To start with the human resources from the public infrastructure digital commons. Citizens have doubts in using and trusting a platform that makes use of a substantial number of volunteers due to their perceived risk of unqualified volunteers causing issues or not having the skills to govern and manage these platforms effectively. This issue includes their data being managed by those who are not qualified, but also regarding volunteers having their biases influence the platforms or overpromising and underdelivering. This concern of volunteers was visible in quotes such as from (F, 65+) on the risk of volunteer bias: “if it's a volunteer site, you always have somebody who puts his mind in it and I don't want the opinion of somebody or his mind what he thinks it should be” and (F, 65+) also saying: ”If you've learnt about it then it's OK. A lot of common people don't know”. A second participant (F, 26-35) says about volunteers overpromising: “I think these volunteer platforms would then have to be careful in what they promise, or they do, as in what aspects they cover. Some aspects are just better left to the government or like profit organizations. Because there can be risks”.

7.1.2 Digital Common structure

The results also showed that it is important that there is a professional governance structure in the digital common if they are to trust them. Citizens want structured organizational systems behind the platforms with both hierarchical positions and clearly defined rules, as well as a democratic governance system with room for everyone to have their voice heard. Quotes that highlight this factor come from, for example (M, 26-35), who talks about the need for leadership: “Like, everyone has the same power, and therefore it will become a real big mess”. Meanwhile a more direct quote on governance is from (F, 18-25): “Definitely like a board. I can't say really like a board of directors, but kind of like that, where they would look over all the important aspects” and as mentioned by (M, 18-25): “I'd say structured, like how structured the organization is, is a big factor in the place”.

7.1.3 Conflict resolution

Also, the mechanisms of effective conflict resolution within the digital commons are a factor in citizen adoption. Citizens felt that disagreements were unavoidable within the digital common and feared that these arguments could lead to significant drawbacks and issues with their participation. Conflict resolution must be considered with objectiveness, equality, and formal systems. Examples of this factor come from multiple interviews, as one participant (M, 18-25) said: “Like if they are fighting or discussing … like a favoritism in a sense will be a problematic it should be objective.” Showing the need for objective systems where arguments are not decided based on favoritism within the digital common. Another quote of interest, this one demonstrating the need for equality comes from (F, 18-25), who says: “When you have like internal fighting, then that’s why you have multiple people on the same level as you, because everyone has a right and a say-so in that case”.

7.1.4 Transparency

Lastly, transparency was seen as important by citizens when using public infrastructure digital commons, with citizens requiring transparency in various aspects. Although the aspects that citizens wanted transparency from might differ, the core of the citizen adoption challenge remains the same, with citizens wanting honesty and relevant information from the platforms. Examples of aspects for transparency are the need to be transparent about the information that is presented on the platform, transparency on the working methods used by the platforms, and transparency on the data used and collected. This challenge therefore requires the structure of the digital common to be adjusted to ensure transparency. As put by (M1, 56-65): “they know a lot about me and what I do on the internet. But then they are not honest in this. But if I don’t accept this, I can’t use the site. So I don’t like that, but I have to accept it.” When asked what factors are important for them to participate in these platforms (F, 46-55) says: “I would say a transparent way of working”, pointing out that transparency is needed for the methods of these platforms. Meanwhile, regarding transparent information (F, 26-35) says: “for the information, that you tell the user about the information and where it comes from. So that is also a type of security, and very important”.

7.2 User platform utilization challenges:

The second key dimension was the user platform utilization, where the challenges have to do with the ease of use of the digital common and the level of effort that must be put into making

use of public infrastructure digital commons. This dimension refers to citizens going on these platforms online and using the platform for their intended purpose. Within this dimension are several aspects, such as the ease of use in the sense of navigating the platform, the understandability of the information and content of the platform, but also the visual appeal of the platform and the ways that there are support mechanisms available if needed.

7.2.1 Ease of use

Starting with the ease of use of the platform, each interviewee mentioned this factor. Citizens made it noticeably clear that for them these public infrastructure digital commons need to be easy to navigate on every level and that they want it to take little time and effort from their side to get from these platforms what they need. The ease of use was mentioned throughout the entire process of using the platforms, from the start with potential logins of the platform, to the initial scan of the platform when they arrive on its landing page, to performing the task for which they come to the platform. This was visible through quotes, such as from (M1, 56-65) who responded to what was his most important factor: “easy to use, because if it's not a good infrastructure on their sites, now I can’t use it”. Other quotes of interest on the importance of ease of use were from (F, 65+) who said: “if I really don't know what to do, I leave it I don't ask for help. I leave the sites alone” and from (F, 26-35), who claimed an issue when using platforms was: “Finding everything I need”.

7.2.2 Understandability of information

For citizens to successfully use digital public infrastructure, there is also the need, besides the technical ease of navigation, for the information on the website to be understandable to the wide range of users that come across the platform. Citizens reveal that if the information provided on the website is too difficult for them to understand that this gives them less reason to use these platforms, as this limits the usefulness of the platforms. This understandability of information challenge comes in different forms, such as with information not making clear what they require from the user, or secondly that the general level of the words used is too difficult for many users, or even the language which can cause problems for those speaking a different language than the platform is using. This factor was visible in multiple interviews with the issue being raised through quotes indicating different aspects. For example, with (M, 18-25), raising the issue of lack of clarity: “Sometimes it doesn’t make sense, maybe intentionally. They want to keep it simple, like, straightforward, but then you’re left thinking… they don’t guide you clearly”. Another quote on the understandability comes from

(F, 65+): “The explanation has to be so the simple people understand, yeah. You have government talk, but simple people cannot understand, and that's important”. Also, language can cause problems as (F, 18-25) says on their use of digital public infrastructure platforms: “Whether it has an English language option, a lot of websites don't have that”.

7.2.3 Visual appeal

The interface of public infrastructure platforms was also mentioned as one of the barriers to their use, as citizens find the looks of platforms also important. There were many parts of the interface mentioned, such as the colors, the pictures used, the “warmth” of the platform and how much they stand out, so that they can create their own identity. Some examples from the interviews include: “The “look-like” of the site is also important. If the “look-like” is not easy and nice, I throw it away because it takes much time to use”, as said by (M1, 56-65). Other quotes are from (M, 18-25): “Contrast matters a lot. Sharp, bright colours are really annoying”, from (M2, 56-65): “it's cold and it's technical. And that's bad”.

7.2.4 Effective assistance

The last part of the user platform utilization was that citizens often have challenges with getting effective support and require a wide range of options. This led to the citizens making clear their demands for effective assistance from the platforms if they are to use them. The citizen demand for assistance comes in two ways, with citizens requiring multiple forms of assistance and secondly needing assistance to be skilled enough to be able to help them solve the issues that they face.

This issue can be seen through quotes by many interviewees, such as from (M1, 56-65): “it takes a lot of time, but it doesn’t have to be so complicated … if they help me well, then yes, I will come back more” or through the quote from (F, 46-55): “Not everybody is very handy or something like that, and, yeah, that will cost money as well. So then you have to, but it's worth it”. Meanwhile there were also mentions of the need for different types of assistance, as put by (M1, 56-65): “I want solutions to be available, yeah, because it still helps, even when I do not use them”, with an often-named desire being chatbots, as put by (M2, 56-65):” There's a huge knowledge in those systems, but you can really talk to that AI as if it's if it's a person. So that makes it easier to use”.

7.3 Citizen contributory participation challenges:

The third dimension of challenges is regarding citizen contributory participation where citizens felt that they needed to be convinced to participate in a contributory manner. Contributory participation refers to participants becoming active within the digital common and investing time in its maintenance and development. Citizens showed that due to past experiences they did not feel heard and that they desire only to contribute to causes that they are passionate about and belief in. This dimension contained the element of giving feedback, where citizens both felt reluctant to consider giving feedback and needed to believe that the feedback that was given would be processed. The other aspect was that contributing participation required both the ability to make an operational impact, and an impact on the community that they want to serve.

7.3.1 Convincing users

Firstly, looking at the challenge of convincing users to give feedback. The user reluctance to provide feedback stems from multiple aspects that cause hesitance from the users, such as their past experiences where they felt their feedback made no impact, their lack of belief in their ability to give good feedback and their annoyance with lack of outreach from the platform side where they feel the burden is on them.

This reluctance can be seen by quotes such as from (M1, 56-65): “You don't get your benefit. You don't actually feel like it helps so then I think why would I help them”, Other quotes are from (F, 65+): “I don't believe that they want my help because I'm not good enough with those things” and on the outreach (M2, 56-65): “The initial action should come from the developers, from the owners of the website and not the other way around”.

7.3.2 Feedback processing

Citizens also mentioned that it was important to them that if they are to participate in these public infrastructure digital commons, that these platforms listen to their users and that user feedback has an impact. Feedback has to cover wide aspects, such as making use of feedback on the general process and the understandability and there is a need for systematic methods for this feedback to be developed. The importance citizens place on the processing of feedback by these platforms can be seen in quotes such as that when platforms have feedback mechanisms it improves the opinion of the platform since: “they value the user's opinion”, as said by (M, 18-25). Other quotes about the importance of using feedback are from (M2, 56-

65): “if you don't talk to your users and see how your users use your website while you're leaving, a huge part of your development, you leave it out”, and from (F, 26-35): “as an organization you can learn from complaining. And I think the learning aspect is very important for a volunteer organization”.

7.3.3 Participation impact

The last challenge was that citizens' participation is highly dependent on the perceived impact they can have from their participation. This impact comes from two sides. Firstly, citizens need to feel that they have an impact on the organization. This organizational side looks at impacting the decision-making process and the operational aspects of the digital common. On the other side is the impact on the community, where citizens need the feeling that their contribution makes a societal impact, where their volunteering creates benefits for their community and society.

This can be seen in quotes on the organizational side such as from (M, 18-25): “I guess some kind of freedom, like having the freedom to design or redesign it a bit” or with a quote from (M, 26-35): “if it's done in a way that is secure, in which everyone has the same power, there's no hierarchical structures, that would invite me more”. Meanwhile on the impact of participation on the societal sides, (M2, 56-65) on the impact of having passion for it compared to working on a website that you get paid for: “So you don’t put your heart into that website [Which you get paid to work on]. And I think that’s the biggest difference between the two”. Another quote on the societal side is from (F, 26-35): “I think social impact is very important”.

7.4 Social and inclusive impact challenges:

The fourth dimension is the social and inclusive delivery impact. Citizens find it important that the platforms end up making an impact in ways that they consider important. This means that the delivery must be effective, and that it provides access to all people regardless of background or ability. This links to the found need for communality, where the service provides for the community and the digital common has to feel like a community itself.

7.4.1 Performance expectancy

This dimension starts with the aspect of performance expectancy. Citizens were adamant that these platforms had to provide benefits through helping solve real challenges they faced. If the

platforms failed at convincing citizens that the use of them brings benefits to the citizens' lives, then the citizens explained that they would not make use of them. Within this challenge, citizens also compare the platform to alternatives when mentioning the performance of the platform. This dimension can be seen in quotes such as by (M1, 56-65): "you don't use them for fun but to solve problems. Otherwise, I wouldn't use them", or in a quote by (M, 26-35), who makes his use of the digital common dependent on: "How effective the platform would be in achieving what the goal is".

7.4.2 Accessibility

Citizens also found accessibility important, as the right of all people to use these platforms was seen as highly relevant to the citizens. Specifically, interviewees thought that public infrastructure digital commons should, as the name suggests, be for the public and common people. Accessibility came forward in different forms, with elements of stakeholder management, digital literacy and a general mindset that considers all people being mentioned as key factors for these platforms to safeguard. Regarding the stakeholder management, one interviewee (F, 26-35), said: "It needs to be accessible for everyone and every layer of the population, so that's very important", pointing to the need for platforms to consider a diverse group of users when making decisions. On the digital literacy gap, one interviewee (F, 65+) said: "Because of our age, it's getting more difficult, … are not educated enough to do all those things on the web,", while another interviewee (M2, 56-65) also mentioned digital literacy: "if you're young, you know what you want. … If you're 80, you don't know what is there. So, the weakest link needs the most attention".

7.4.3 Communality

The last part of the dimension is the community purpose and social impact of public infrastructure digital commons. This factor specifically came up in the context of digital common participation, where for citizens to be willing to invest time in the governance and upkeep of these platforms they require that the digital common ends up becoming a community which feels good to be a part of. This factor refers to both the purpose of the platform, where firstly it serves the needs of what they feel benefits the community and the people themselves, which are needed to give it a community feeling. While secondly, people are nice to each other and willing to help each other. This factor can be seen in quotes such as from (F, 65+), who initially is not interested in participating, but does say on local community initiatives: "We are involved with that as well. So local I like". On the human-side of the

community feeling another participant (F, 46-55) says: “it would matter to me what they are doing, and also if the people volunteering for the platform are nice and good people.” Also showing that the citizens need the platforms to feel friendly and social for them to participate. Lastly, citizens also talked about the need of having these platforms serve the community interests, as put by one interviewee (M, 26-35): “if it’s done from the users themselves, there will always, yeah, it will be a product that is more in line with what people want and need instead of, like, something that’s done top-down”.

7.5 Data management challenges

Data management challenges also came forward in the analysis as a factor influencing user platform utilization. The data management challenge has two parts to it, one being privacy, while the second being data security and protection.

7.5.1 Privacy

Looking first at the citizen desire for privacy, interviewees feel that their private data is of no business to the public infrastructure digital common platforms and that this factor needs to be carefully considered by these platforms as they do not like that their information is collected. Within the privacy factor, elements such as their dislike of cookies and being tracked, and their lack of understanding of why certain parts of their private information were being tracked by these platforms were mentioned. In addition to a lack of understanding, the nature of the information was also of importance, where private information was more important to be protected than general data. As one interviewee (F, 46-55) said: “sometimes I use the incognito mode. Well, most of the time. So in general, I think privacy is very important for me when using these sites”. This quote shows that the need for privacy directly affects the way that citizens use the internet and that they take this desire for privacy seriously. Another interesting quote of an interviewee (F, 18-25) was: “if it's just me going onto the website to check something, then I don't think it's necessary for them to track my IP address”, showing that citizens are aware of what parts of their data is being used and that they make considerations on the basis of whether they find this justified.

7.5.2 Data security

The second part of trust in data management was data security. Although similar to privacy concerns, the need for data security was named as a separate citizen adoption factor from

privacy concerns. This challenge does not focus on what is being tracked by organizations and why. Instead, this challenge comes out of the direct need of citizens for the platforms to have strong data security protection measures, both technical and organizational. Citizens showed restraint to using platforms if they perceived there to be a significant risk for data leaks or mishandling of data as these risks are not acceptable to them. Similarly to general privacy, the challenge becomes more important when dealing with information that is perceived to be of higher importance to citizens.

Interviewees noted examples such as (M, 26-35): “If it's just information between the people in your neighborhood, perhaps security is less, yeah, less of a factor.”, showing that the nature of the information is of relevance. Meanwhile, another interviewee (M, 56-65) mentioned the need for legal compliance when it comes to data, asking questions such as: “well, how did they implement GDPR”. The citizens also talked about need for these platforms to have good protocols, as Interviewee (F, 26-35) said: “If the organization has a good security protocol and baselines, I believe that there is a possibility that there is less chance to have a data leak”.

7.6 Organizational capabilities solutions

The organizational capabilities solutions can be placed in three different themes, Human resource management (HRM), formalization, and collaboration. Firstly, to solve conflict resolution challenges organizations make use of formalized and proven conflict resolution processes, such as put by interviewee (E1): “The center for effective dispute resolution is in the Netherlands or Brussels or somewhere like that. It's a really clear process. That's now proven to work well”. Besides making use of these proven processes, organizations also look at hiring and partnering with third-party organizations that can give objective judgements to conflict. To solve the challenge of volunteer capabilities not being sufficient there are HRM mechanisms employed, starting with a recruitment process that tries to find the most suitable volunteers to be deployed to the correct spots. Another thing is that there are role-specific guidelines available that help volunteers gain a better understanding of their tasks and what they should do. Organizations also sometimes offer compensation to volunteers, as this is needed to widen the range of volunteers beside only the people who have free time on hand and get to a point where the organization has a diverse and qualified group of people. There are also workshops hosted by the communities to give in-person trainings, as put by (E8): “By, for instance, organizing workshops and also pre-workshop sessions that are specifically

targeted towards engagement of people who are less familiar with digital technologies or have no experience or background". Like the recruitment process, the organizations also gatekeep certain positions away from the volunteers and only allow experts access to these positions. Lastly, collaboration is also important to train volunteers with external organizations being used to provide assistance to volunteers.

Regarding the challenge of professionalizing the digital common the first solution is to have a code of practice which includes the rights and responsibilities of members of the organization. As put by (E4): "So a good kind of code of practice is important. I mean this is something that's very important". There is also a need for an executive and oversight board, which are also bound by the code of practice for what they can and cannot do. To professionalize the organizations, they also must set up controlling and monitoring processes to ensure accountability and understandability of what happens in the organization. Lastly, a professional map of potential partners must be created, and organizations must collaborate with relevant partners to create a network. For transparency organizations share all relevant information in a central place on the platform and again make use of the code of practice to make everybody's rights and duties transparent. Lastly outside of the specific citizen challenges, the results show the large democratic aspects to organizational capabilities in the digital common. As organizations let participants vote on councils, the code-of-practice, the role-division and financial aspects. As put forward by (E2): "Based on voting, basically, people can sign up if they want to do it, and then we as a community can vote. It's democratic." And (E4), talking on the code of practice: "We democratically decided the rules".

7.7 User platform utilization solutions

The solutions to the user platform utilization challenges can be categorized into the categories of researching, conscious designing, and personalizing support. For the ease of use of the platform, organizations make use of UI/UX designers who, through their expertise, can deliver better user experiences. The organizations also make use of API developers, who make sure that the processes behind the scenes can successfully communicate and cooperate with each other. The organizations also create different prototypes which are then tested with users, and they also perform qualitative research where they talk to citizens on what they want to see in the platform processes, as put by (E7): "What we then do is ask what a person living

around the airport would like to know. A little bit based on what his experience is". To the challenge of the understandability of the information on the platform there were two solutions found, one being to turn the complicated deeper insights and turn them into simplified graphics that tell the users what they need to know, as (E2) said, "Make it as simple as possible. So don't show very complicated graphs with all information combined. But group them into smaller graphics". The other solution was that they researched different stakeholders and saw how they wanted the information given to them to provide better customized ways of showing this information. To increase the visual appeal, again UI/UX designers are employed, while also research is performed through focus groups. Lastly to solve this challenge the interface is gamified, where the organizations make use of ISO standards that are accepted by scientists for the program and put gamification on top of this, as (E5) quoted: "Have a standard scientific based accepted by engineers and then we put on top gamification for the user". The last use challenge had to do with effective assistance, for which multiple solutions were found. The first solution is to have different types of support based on the request, as put by (E1): "Every request has three options for solving that request. The first option is education, so they might get a little bite sized how to or an explanation of what a particular feature is…the second option, which is configuration, like we just need to configure some elements of the platform to satisfy that particular need. Like say switch on air quality information gathering... And then the third option is development". Other organizations allowed leadership to be directly called if people needed support, while another organization makes use of a commission with different types of stakeholders to provide assistance to the users. For bigger groups that require assistance, webinars are also given allowing for a central point of assistance, while lastly for smaller communities directly people from the community were called upon to help each other when they required help.

7.8 Citizen contributory participation solutions

On the solution side for the citizen contributory participation challenges there were again three different themes of solutions found, being marketing, personalization and feedback integration. To solve the challenge of feedback processing, organizations ensured that they combined different channels of feedback from participants. The organizations also make use of analytics to be able to classify the feedback by making use of tags, codes and a ticketing system in which priorities can be set. Participatory design was also used, as put by (E8): "We have a kind of participatory design methodology. So every, citizen engagement is using that

model so you can see it as a template". This method ensures that participants are involved in the design and that their feedback is processed and considered in the different steps of the design. Other organizations allowed participants to put their feedback to a vote in the democratic sessions, giving participants a guarantee to have their feedback considered by the platform. The last solution to processing feedback was to take the feedback that ends up making an impact on the policy of the platform and sharing this in the open and making it very visible that feedback has an impact. To the challenge of convincing users to give feedback, there was a need to make use of the correct outreach channels, which depend on the audience. Other organizations provide voucher programs to incentivize people, as put by (E5): "Then give a specific voucher to these small villages, shopping malls, really within the local community". This solution also ensures that the money remains in the community. Organizations also use outreach through in-person events, where they can directly get visitors to participate even if they have not yet done so before. Social media presence was also used, with platforms such as Facebook being used to let people know what the organization is doing. Convincing people to participate was also done through targeting relevant stakeholders directly, instead of aiming for random citizens to participate and hoping to find those who can contribute. Lastly, the organizations used their own personal networking to convince friends, family and neighbors to join the platform, trying to leverage their relations to get people to give it a try. For the last challenge of ensuring that volunteers can make an impact there were also solutions. This was done firstly by giving freedom to the citizens to adapt their input, as organizations provide freedom and opportunity to have local input. This input is then through engagement with them adjusted to make it more relevant to the neighbourhood and community. Another solution given was through storytelling, where citizens are told the story of how it benefits them and in what ways these tools such as digital twins can help them and their community, as put by (E4): "We have to tell the story, we have a strong message on the benefits of this of using these tools and really of using digital twins and what people can do and what people cannot do". Lastly when citizens choose to participate organizations give their own metrics for success, which they can easily see on their own account and gives them an easy overview of their impact.

7.9 Social and inclusive impact solutions

Then there is the dimension of the social and inclusive impact of the platform, for which the solution themes were citizen-centricity in performance, citizen empowerment, and social

engagement. The first challenge here was the need for communality, ensuring a social and connected feeling. To ensure this, organizations host events such as BBQs in the community. Another organization hosts open events in their community center, where they create a friendly atmosphere that leads to people coming to the sessions even when they do not need anything. Other activities are to create low-stakes fun and social settings where participants can get to know each other, allowing everyone to have their moment to shine and present themselves. Lastly, to foster a sense of community, citizens in these platforms can create their own initiatives with sub-groups which they can invite people to, as put by (E4): “We facilitate citizens to create their own groups and invite others. So I have a kind of initiative or an idea, I can create something. I can make it open. I mean, that's up to me, as a citizen then”. To solve the challenge of accessibility, solutions were to leverage technology to empower citizens, for example by having text-to-voice so that people with visual hindrances can still independently make use of the platform. Other solutions were to send people out and see how people with different backgrounds or people with disabilities would use the platform and then find ways to adjust the platform, as (E7) puts it: “We send somebody out with a preview to interested persons with different backgrounds and see what they would like to see anyway and then from that work on well, if it's possible. How can we do that? What would be the best thing to do and keep into account things like, color blindness or not good vision.” Lastly, the organizations made use of bottom-up strategies, which allow citizens to create their own platforms, mitigating the risk of experts with a disconnect to the users to create inaccessible platforms. For the platform performance challenge, there were also multiple solutions. Firstly, platforms let citizens set the metrics of their platforms to ensure that they are measured by the wishes of citizens, as put by (E1): “From a citizen perspective, they just set their metrics and then we play that back to them”. Secondly, the systems were created with the user directly at the front of the platforms' minds. Metrics were also tailored so that they were relevant to a wide range of different stakeholders. Performance was also ensured through certification and ISO standards. Lastly, the impact of the platform was demonstrated through using objective professional measurements, acknowledging that the platform takes the community seriously.

7.10 Data solutions

To resolve data challenges, there were two themes found, one part being communication of privacy, and the other is data safeguarding. To solve privacy concerns, the solutions given

were to “Cartoonify” the privacy explanations, as this makes the explanation more straightforward and can remind the citizens of their rights. Besides this, the organizations also offer one-on-one meetings to give in-person explanations regarding privacy concerns if it is needed for the citizen, where organizations communicate messages on how much they care for privacy, as put by (E3): “We need to tell our citizens clearly that privacy is very important to us”. The organizations also create clearly defined consent forms, specifically mentioning what third-party organizations also have access to the information they provide. Lastly, organizations also communicate the data security systems and protocols that they use, so that citizens can make their own informed decision on whether they trust the quality. On the side of the challenge of adequate data security, solutions were given that are more behind the scenes. Firstly, organizations minimize the data they collect, so that there is no data on the servers that is not needed. Part of this was also that the organization ensured that data was also not kept longer on the servers than needed. Secondly, organizations make use of state-of-the-art security systems, as this ensures all available measures that you can use for data security are employed. These systems, once employed, are also regularly tested by organizations, with partnerships too, leading to continuous improvement of the data security system. Other measures organizations employ are to make the collection of data dependent on the type of use of the platform, as (E2) puts it: “we use as little as possible, but it's defined based on roles”, meaning that simple users have less of their data collected. Lastly, to ensure data security organizations follow regulations, such as the GDPR, or other acts such as the AI act.

8. Discussion

This research looked at the different citizen adoption challenges associated with public infrastructure digital common twins and looked at ways that organizations address these challenges. It was uncovered that there were challenges in five different areas, these areas being organizational capabilities, user platform utilization, citizen contributory participation, the social and inclusive impact, and lastly data management. For each of these dimensions and their challenges, solutions were identified through interviews with experts from the organizations that work in public infrastructure digital common twin organizations. Based on these dimensions, a conceptual model, which can be seen below in figure 3, was formed to explain the interplay between the different dimensions. These dimensions represent the themes of capabilities that organizations employ to try to achieve success and solve

challenges. The capabilities here are considered through the lens of dynamic capabilities, which are routines that allow firms to rearrange their resources based on changing environments (Eisenhardt & Martin, 2000). The discussion is structured in accordance with the conceptual model. Looking at the model, organizational capabilities encourage user platform utilization and citizen contributory participation. Meanwhile, user platform utilization and citizen contributory participation contribute to the successful social and inclusive impact of the public infrastructure digital common twin. Lastly, data management moderates the relationship between organizational capabilities and user platform utilization. This model is shown and further explained in the discussion below. Table 5 also shows a summary of the dimensions and the themes they came out of, highlighting the capabilities employed.

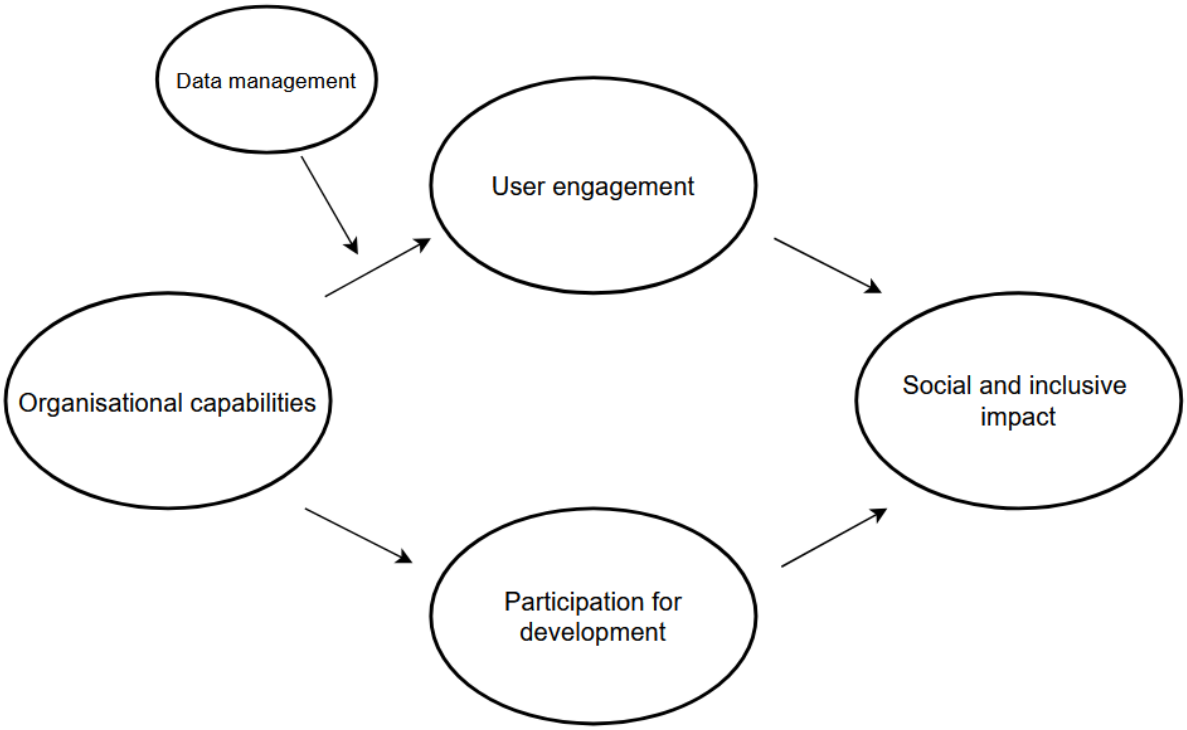

Figure 3: Conceptual model of the results

Table 5: Summary of the model dimensions

Dimension	Challenge themes:	Solution themes:
Organizational capabilities	Conflict resolution; Volunteer capabilities; Digital common structure; Transparency	Human-resource management; Formalized governance processes; Collaboration
User Platform Utilization	Ease of use; Understandability of information; Visual appeal; Effective assistance	Researching; Conscious designing; Personalization of support
Citizen Contributory Participation	Feedback processing; Convincing users; Participation impact	Marketing; Personalization strategies; Feedback integration
Social & Inclusive Impact	Platform performance; Communality; Accessibility	Citizen-Centricity; Citizen empowerment; Social engagement
Data Management	Privacy desires; Data security	Communication; Safeguarding

8.1 Organizational capabilities

8.1.1 Digital commons unique governance

Organizational capabilities for public infrastructure digital commons were found to be relevant to citizen adoption; however, they require a different approach than traditional organizational capabilities. Digital commons differ in organizational structure compared to traditional organizations, with aspects such as open-source, democracy, and collectivism as part of their foundation (Bühler et al., 2023). They cannot be managed using traditional managing standards due to their unique socio-economic approach that has to integrate and navigate legal structures, ideas of ownership, economic structures, and governance mechanisms (De Rosnay & Stalder, 2020). Instead, digital common governance principles include inclusive-decision-making, collective resource ownership and partnerships without power imbalance (Albareda & Sison, 2020). Still, findings indicated a need for careful structuring to ensure successful citizen adoption, with a high degree of democracy, aligning with typical digital common governance. The aspect of democracy differs from traditional organizations which have ownership structures and corporate governance in which dominant shareholders play influential roles in the structure and management of the firms (Konijn et al.,

2011). Still, organizational democracy does exist already; however, it allocates different democratic rights based on the stakeholder (Harrison & Freeman, 2004), therefore differing from this study.

8.1.2 Building organizational capabilities

The importance of organizational capabilities comes from the fact that they seem to be a prerequisite to citizen platform utilization and contributory participation in the platform. As the findings indicate, organizational capabilities positively influence citizens' willingness to use and participate in the digital common. Challenges in this dimension are volunteer capabilities, digital common structure, conflict resolution and transparency. Therefore, the findings indicate that building organizational capabilities, through human resource management practices, formalization of governance and setting up collaborations with partners are relevant to the success of public infrastructure digital common twins. This aligns with the framework of the dynamic capabilities in the context of the resource-based-view, where organizations through their management capabilities of coordination and deploying organizational competencies achieve success (Teece et al., 1997). Organizational capabilities in this research are exemplary of the focus of the resource-based views, as they are the direct management of resources through formalization and pre-defined processes. This aligns with dynamic capabilities, which are the organizational strategies and procedures through which resources are structured to respond to emerging challenges (Eisenhardt & Martin, 2000). The formalization finding of this study lays this foundation, as both citizens wanted structured governance, and organizations presented their use of formality in governance. Formalization levels, however, must be fine-tuned, as too much or too little formalization encourages turnover (Kaufmann et al., 2022). This is because too much formality limits worker freedom to make their own impact, while too little formalization causes organizational objectives to become watered down for workers (Kaufmann et al., 2022). The results showed that to solve citizen adoption challenges, formal structures focus on processes, without formal authority being assigned to leadership. Literature also shows that formality is valued for control and monitoring by management, but leaders should diverge outside of formality to motivate members (Bromley & Meyer, 2021). When looking at the citizen adoption challenge of lack of volunteer capabilities, the solution of human-resource management practices is interesting, as for a non-profit organization, the use of volunteers means that there is a workforce that receives little to no compensation, requiring other motivational methods and structures (Von Eckardstein & Brandl, 2004). The solutions also included recruitment processes and

restricting access to key parts of the digital common. These practices are rare since it is not considered appropriate for volunteers offering up their own time, however this approach is posed to have a potential positive effect on the performance quality and costs for non-profits (Von Eckardstein & Brandl, 2004). Lastly to deal with the citizen adoption challenges collaboration is used to increase organizational capabilities, aligning with literature which finds that non-profits form partnerships for resource access and sharing, organizational learning, improving communication, building networks, and accessing diverse perspectives (Kassem et al., 2021). It also aligns with inherent values to digital commons, which encourage collaboration between communities, merging into bigger networks (Albareda & Sison, 2020).

8.2 User platform utilization

8.2.1 Need for user platform utilization

The second dimension was user platform utilization, where citizens make simple use of the technology to utilize the platform for its intended purpose. To solve the challenges citizens face in this stage, which are about the ease of use, understandability, visual appeal and effectiveness of assistance, organizations make use of multiple capabilities. These are conscious designing, researching user preferences and personalizing support to users. The need to solve user challenges was found in other studies as well, with a lack of technological competency being identified as a barrier to citizen participation in smart-city initiatives (Shin et al., 2021), while user-friendliness of technology is also a significant barrier to technology use (Morte-Nadal & Esteban-Navarro, 2025).

8.2.2 Meaning of the solutions

The solutions of conscious designing and researching are connected, as organizations require the use of skilled designers, while having a user-centric mindset. These solutions solve challenges regarding ease of use, understandability and visual appeal, demonstrating that they solve multiple citizen adoption challenges simultaneously. Literature also stresses this combination for platform design, with the need of acquiring designers for human-resources, which must be combined with analyzing the customer segment desires, specifically their troubles (Steffen et al., 2023). Gamification is also an interesting finding, which is part of conscious designing. Gamification effectively engages humans in digital activities that require cooperation to achieve, such as knowledge and information management (Riar et al., 2022), aligning with the citizen adoption challenge for digital commons. For individual activities,

gamification employing personal objectives is successful in encouraging use and is posed to positively impact users' word-of-mouth to others (Wolf et al., 2019). For solving effective assistance challenges, customized personal assistance solutions are offered to ensure it fits with the needs of citizens, with for example different classifications being employed for requests determining what needs to happen with them and direct contact being possible with leadership. Noticeable is that the solutions for assistance are mostly human based, with few technical solutions being employed. Meanwhile, many citizens spoke positively about technology solutions, such as chatbots, widely mentioning their appreciation of their availability. However, the lack of technological solutions aligns with findings that show that low-technology solutions are preferable for non-profits, as it prevents spending unnecessary resources on IT support (Zubler et al., 2024). However, this finding is interesting in the setting of digital common themselves, which inherently employ technology solutions to deliver their services.

8.3 Citizen contributory participation

8.3.1 Importance of citizen contributory participation

Citizen contributory participation entails citizens becoming active in the development and maintenance of the digital common, which is highly relevant for digital common. This importance is because without citizen participation in the production and maintenance, digital commons are unable to sustain themselves and will fail to raise a representative variety of views (De Rosnay & Stalder, 2020). This dependence on citizen contributory participation represents a more unique aspect to digital common organizations, as commons inherently are resources shared by a community, managed and preserved through collective cooperation (Fuchs, 2021). This calls for serious measures to be taken to ensure citizens' barriers for participation are removed. Evidence of this challenge is seen in literature, where a case study found that 70% of users did not contribute and of the participants that made contributions 1% of them were responsible for 50% of the contributions, showing an issue of free-rider behavior (Greco & Floridi, 2004).

8.3.2 Understanding the solutions

Challenges for citizen contributory participation were about feedback processing, convincing users and ensuring participation impact. The solutions to these challenges were marketing, personalization strategies and feedback integration. Marketing is used to convince users to

participate, by using different channels, while employing targeting strategies to reach the right people. The solution of marketing in the context of non-profits is not unique, as it builds relationships with volunteers and other stakeholders, while improving the brand image through increasing awareness of the purpose of the organization (Werke & Bogale, 2023). Personalization was also used as a solution, as organizations use actions such as storytelling to tailor messaging on how it can benefit the citizen and their life. Storytelling is a powerful tool, as for non-profits, spreading a narrative is more successful for persuading people than simply communicating information, with storytelling being more successful when aimed at individuals than groups (Van Laer et al., 2018). To get citizens to contribute, stakeholder engagement is also used, as this allows organizations to adapt their work to align with stakeholder interests. Stakeholder engagement is a driver of creating social community spaces, which allows for two-way information flows between organizations and external stakeholders (Kujala et al., 2022). Lastly, the integration of feedback was an important solution to citizen contributory participation. Within these practices there are solutions like participatory design and visualizing volunteer feedback and contributions. This solution of visualizing volunteer feedback link to findings showing practices that recognize volunteers for their work increase retention rates (Hager & Brudney, 2011).

8.4 Social and inclusive impact

8.4.1 Requirements for impact

For citizen adoption there was also the need that the impact of the public infrastructure digital common twins is effective, social and inclusive. The citizens do not specify the need area of impact in the research but say it must solve real problems they face effectively and reliably. For this impact to be made, needed are the utilization of the platform and the citizen contributory participation, as digital commons are intrinsically community-run and therefore require the community to maintain them (Fuchs, 2021). Meanwhile, the user utilization is also needed to create an impact, because when smart-city technology is not used it has no actual purpose or abilities (Capdevila & Zarlenga, 2015). Within the social and inclusive impact, citizens want the platform to deliver what it is supposed to, while ensuring accessibility to all and ensuring the digital common feels like a community.

8.4.2 Approaches to ensure impact

To solve these citizen adoption challenges organizations use a citizen-centric performance approach, empower citizens and make use of social engagement strategies. Looking at the citizen-centric performance approach, the organizations ensure that their performance is measured through metrics that consider their stakeholders. They also ensure that the performance is of a high level through using high standards to ensure quality and using objective measurement metrics to give a fair image of their performance. As non-profits, they have different performance measures from for-profit organizations. Instead, non-profits often consider three main factor areas for their performance metrics, which are social factors, stakeholder-related factors and managerial factors (Treinta et al., 2020). However, in the study it was found that digital common organizations also let the citizens themselves set their metrics, which might lead to metrics differing from traditionally used factors. Under the social and inclusive impact also falls the challenge of accessibility, which was mainly resolved through citizen empowerment, giving control to the citizens. This solution is ingrained into digital common organizations, which through giving control to citizens, empower people and their communities, which strengthens people's independence and dignity (Murillo et al., 2024). Social engagement was also used to ensure that the outcome of the digital common ensures a communal feeling, by for example hosting events and ensuring fun and social interactions within the organization and outside of it.

8.4.3 Areas of impact

Considering again that for citizen adoption the end-goal of social and inclusive impact must be delivered, public infrastructure digital common twins are positioned effectively to achieve this. For the area of impact, the literature shows digital twins can provide solutions on key different areas, such as urban planning and issues surrounding sustainability (Omrany et al., 2025), but also on social issues such as population ageing, social injustices and other demographic issues (Ravid & Aharon-Gutman, 2022) and issues surrounding safety, such as in traffic (Sohail et al., 2024). Meanwhile digital commons through their democratic functioning give participating citizens the influence to direct the impact to what they deem important, as they are entitled to collectively make decisions about them (Fuchs, 2021).

8.5 Data management

8.5.1 The significance of data management

Lastly, the dimension to discuss and reflect on is the data management dimension. The results show that data management moderates the relationship between organizational capabilities and user platform utilization. Challenges regarding privacy are found often, such as in Gracias et al. (2023), who find that citizens show resistance due to data privacy concerns in the implementation of smart-city technologies. Privacy is also relevant to consider because privacy has been established as a human right but is at stake for many aspects in the smart city due to it involving directly the spaces citizens live in (Eckhoff & Wagner, 2017).

8.5.2 Interpreting the solutions

Within the citizen adoption challenge, privacy and data security are the issues pointed out by the citizens. Organizations had solutions focused on communication of privacy and safeguarding data security. Solutions such as “cartoonified” privacy explanations and clear consent forms are both solutions aimed at lowering the barrier to understanding the implications of written-down statements, meanwhile the solution of one-on-one meetings offers a lower barrier through the ability for citizens to ask for clarification. However, it is important that organizations take a careful approach when simplifying informed consent. This is relevant because when asking for informed consent, both too many options and too few options within consent authorizations leads to the informed consent being found not meaningful, leading to people making uninformed choices (Utz et al., 2019). Meanwhile security solutions such as data collection minimization, state-of-the-art security systems and GDPR compliance show that organizations prioritize privacy and address it early in the process to address citizen adoption challenges. This approach is similar to privacy-by-design, which means that organizations think about implementing privacy from the initial design phase, instead of waiting for issues to arise during the operational phase (Schaar, 2010). The findings here in this study do differ from privacy-by-design due to the huge importance given to the ways of communicating privacy, instead of merely focusing on the technological side.

8.6 Theoretical contributions:

8.6.1 Digital commons linked to UTAUT

This study contributes to the theoretical framework of the Unified Theory of Acceptance and Use of Technology (UTAUT) (Venkatesh et al., 2003), as this was the first time this theoretical framework was used to explain the acceptance of digital commons. What makes digital commons interesting in the context of UTAUT is the participatory aspect, where the acceptance of this technology has two paths. One part is platform utilization, which is in line with other technologies. However, the contributory participation aspects distinguish the digital common from other technologies. Therefore, by researching this unique aspect in the context of UTAUT, this research contributes to its field. Aspects similar to the UTAUT aspects of effort expectancy, performance expectancy, and facilitating conditions can be seen in the research. Aspects resembling effort expectancy are mainly in the user platform utilization challenges, where ease of use and understandability are key, meanwhile aspects resembling platform expectancy can be seen in the social and inclusive impact with platform performance being a direct challenge theme found. Factors that resemble facilitating conditions are the organizational capabilities, as facilitating conditions in UTAUT include the belief of people that the organizational and technical infrastructure is good enough to support the system (Venkatesh et al., 2003), resembling aspects such as the digital common structure, the volunteer capabilities and the transparency mechanisms. Factors for social influence were not found, with peer pressure not being named, however this partially aligns with UTAUT as this is a voluntary adoption setting while social pressure is found to be stronger in mandatory adoption settings (Venkatesh et al., 2003).

8.6.2 Digital commons and the resource-based-view dynamic capabilities

Traditionally the resource-based-view considers competitive advantage to be a result of organizational resources (Barney, 1991) and dynamic capabilities (Teece et al., 1997). Considering the earlier mentioned difference in organizational functioning between digital commons and traditional organizations, this research contributes to the resource-based-view. It does so by researching the organizational capabilities from the digital commons perspective and highlighting their approach to solving organizational challenges. Within the organizational perspective, this contains the democratic aspect, where the results showed that digital commons make use of democratic methods to deploy and manage resources. Other

differences include the digital common need for capabilities that get citizens to contribute to the organization and the need for collective ownership. Lastly, the findings of the importance of partnerships in this research, combined with the open-source aspect of digital commons (Bühler et al., 2023) contributes to the resource-based-view perspective which looks at inimitable capabilities to gain an advantage over others. Instead, this research adds to the resource-based view perspective of dynamic capabilities by turning competitors into partners for achieving the organizations' objective. This has implications for the notion that sustained competitive advantage comes from valuable, rare, inimitable and organized resources, as these partnerships encourage sharing resources and capabilities.

8.6.3 Contributions to digital commons

The research also contributes to the academic field of digital commons. This research is the first that investigates citizen adoption challenges and solutions. The research does so by presenting citizen challenges and tangible methods employed to enhance citizen contributory participation and user platform utilization. It adds to the field by taking use-cases and understanding and highlighting the real working methods of digital commons. This research showed multiple tangible ways of bringing aspects such as open-source, democratic self-governance and collectiveness which are fundamental to the digital common (Bühler et al., 2023) into practice for real use cases. The model created can guide digital commons towards improving their citizen adoption, which due to the importance of citizen contributory participation can increase their performance (De Rosnay & Stalder, 2020), while also platform utilization is necessary for digital commons, as without platform use the technology accomplishes nothing (Capdevila & Zarlenga, 2015).

8.6.4 Contributions to smart-city digital twins

Lastly, the research contributes to smart-city digital twins. As the research considers a new function for them by linking them to digital common organizations, instead of the use found in the literature by traditional organizations or governmental actors. The contribution made by this research is that it shows that this technology can also be employed by digital commons, even though the technology is often provided by outside actors. This links the smart-city digital twin to governance structures where communities have the power to choose the purpose for the technology directly based on their own needs. Specifically considering that

urban digital twins can be used for solving social challenges (Ravid & Aharon-Gutman, 2022), there is a benefit to this research providing a framework for how communities can be directly involved in this smart-city technology that involves issues they face. Considering the digital twin context, the contribution also comes from the responsible governance of digital twins which helps advance the sustainable development goals (SDG) of the United Nations, more specifically SDGs 6, 9, 11 and 12 (Tzachor et al., 2022).

9. Practical Contributions

As revealed by the literature and expert interviews, public infrastructure digital common twins are still in their infancy stage, requiring clear guidance. Considering the essential role of citizens in this development, the creation of this practical framework helps those participating in the governance of digital commons to enhance citizen adoption. Although created in the context of digital twins, other public infrastructure digital commons can still use the recommendations. This is because citizens used their own broader past experiences with digital public infrastructure, combined with their norms and ethics to explain their challenges. Secondly, the organizational functioning between different digital commons remains similar, making these recommendations worth exploring. Looking at the recommendations, practitioners should professionalize their organizations with HRM practices, clear governance and formalized roles, ensuring that the organization has clear structures to work with which are clear to everyone involved. These structures should be set up democratically, with all participants having the power to vote and to suggest changes. Secondly, they need to invest in expert platform design and development, informed by research and prototyping using methods such as A/B testing. They also must put user concerns at the forefront of the design while also setting up assessment processes to continuously reflect on the design based on evolving preferences and circumstances. Also recommended is the use of chatbots for providing support, as this solution was appreciated by citizens, but not found in the organizations. For outreach it is recommended that organizations use different channels such as social media and live events and focus on targeted and personalized connections, employing personalized storytelling. Then they need to utilize feedback using analytics, which should happen digitally, combing different feedback channels. Next, they must use performance metrics relevant to stakeholders, while empowering citizens through giving them the power to set metrics and to start their own initiatives. Lastly, practitioners should simplify

privacy explanations to ensure understandability; while personalizing communication of privacy and ensuring they have the capability to comply with regulation as it evolves.

10. Limitations

There are also limitations to consider. Firstly, a major limitation is that citizens in this research did not have experience with public infrastructure digital commons and digital twin technologies. This meant that the research relied on the citizens making use of their experiences with regular digital public infrastructure and then using transferability for this research, although they did receive explanations on the discussed technology. However, the explanations do not substitute for the value of practiced experience with public infrastructure digital common twins. Another limitation is that the citizens, although diverse, were all residents of the Netherlands, which could hamper the generalizability to other countries and cultures, as cultural differences matter with technology acceptance (Hofstede, 2001). Expert sample limitations came from the infancy of public infrastructure digital common twins, making long-term solutions difficult to consider. There are also biases to discuss, starting with the research being conducted by a single researcher, this could lead to a lack of discussion to challenge insights, which gives a risk for individual bias in the interpretation (Habersang & Reihlen, 2024). However, the researcher discussed findings at multiple occasions with other academics to mitigate this risk. Time constraint was also a limitation as deadlines meant that decisions had to be made on the allocation of time on different aspects of the research. For the interviews there is also the risk that with purposive sampling there is participant homogeneity because they all adhere to some common criteria (Guest et al., 2005). Also described in Guest et al. (2005) is the limitation of reaching data saturation, which is difficult due to the often-pre-determined range for the number of interviews and the dependence on the opinion of the researcher on at what point data saturation is reached. This limitation of data saturation also links back to time constraints, which means decisions on the amount of interviews have to be made.

11. Future Research Directions

For future research, there are different routes to explore. Firstly, as this research interviewed citizens not yet familiar with public infrastructure digital commons and digital twin

technologies, future research could interview citizens with experience. Resembling citizens' lack of experience with public infrastructure digital common twins, the project experts also had limited experience due to the novelty of this technology. Therefore, it would be of interest to revisit in the future when there are more and longer-running use cases and to see if the solutions would differ from this research. In the future innovation could also impact the solutions and challenges as innovation will allow for more immersive digital twin cities. Michalik et al. (2022), used virtual reality to increase user acceptance of digital twin cities through improved immersion, but they noted large-scale-validation is needed before it can be rolled out. Future research could also research the effect of cultural differences, as Hofstede (2001) found that the adoption of new technologies is dependent regional aspects such as the GNP per capita and cultural aspects, such as individualism vs collectivism and uncertainty avoidance. Another angle that could be considered in the future is how different types of public infrastructure digital twins impact citizen adoption challenges and solutions as digital twins can differ significantly. An example is from Qanazi et al. (2025), who differentiate between traditional urban digital twins representing physical spaces and social digital twins, which represent social and demographic elements to reflect citizens' lived experience. Lastly, future research could focus solely on citizen contributory participation to allow for a more focused in-depth look at this level.

12. Conclusion

This research looked at the research question of "What key citizen adoption challenges arise from using digital commons in public infrastructure digital twins, and how can they be addressed?". To answer this question, the research conducted first interviews with citizens with different demographics to find out the barriers they face in using and contributing to these platforms. The research identified challenges in organizational capabilities, user platform utilization, citizen contributory participation, social and inclusive impact, and lastly data management. For these dimensions, the challenges were linked to solutions provided by experts from public infrastructure digital common twin organizations. These solutions include, but are not limited to capabilities such as communication, human resource management, conscious designing, marketing, and citizen empowerment. These solutions together with the conceptual model created, form a framework for the citizen adoption for public infrastructure digital common twins. The list of solutions can serve as direct

resolutions to the challenges that organizations face, while the conceptual model can be used to understand and prioritize various aspects of citizen adoption. Within the research all dimensions are important for this framework, but organizational capabilities, citizen contributory participation, and the social and inclusive impact are specifically important findings. This importance comes from the uniqueness of the characteristics of these challenges to digital commons and twins, which provide new insights for practitioners and academics.

13. Acknowledgements

Lastly, at the end of this thesis I would like to extend my gratitude to Dr. Pauline Weritz for her help and guidance throughout this research. Her feedback has been of the utmost importance to raising the level of this thesis and providing me with the capabilities that will help my research abilities in the future. Secondly, my special thanks to Dr. Joschka Hüllmann who, through his expertise in technology and digital transformation, was able to help me place this thesis more clearly within the academic field of technology adoption and innovation. I also want to extend my gratitude to those from the organization that provided me with the research problem that inspired this thesis for all their support and guidance. Additionally, I want to thank all those who participated in this research for their cooperative attitudes and interest in the research.

To conclude, as this thesis marks the end of my time at the University of Twente, I also want to extend my gratitude to all who have supported me over the past four years. Specifically, I want to give special attention to my family and friends who have given me the support, energy, and guidance that prepared me for success and kept me motivated throughout my studies.

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Appendices

Appendix A: Interview Guide: Citizen interviews

Hello, my name is Alvin, and I am researching the citizen adoption of digital public infrastructure (Brief explanation given, also explanation on the consent form).

I would like to ask you for your consent to record this interview so the anonymised interview transcript can be used for analysis purposes.

Hand them their consent form

Then, I will now start recording (Use backup device to record as well)

You can stop the interview when you want, and everything you say is confidential.

Is that okay, or do you have any other questions?

Before we start, I would like to say that you can always ask me any questions if something is unclear, and I would like to share some definitions before we start so we are on the same page here.

In this interview we are talking about digital public infrastructure digital commons, what this means is a combination of:

"Definition DPI": "digital systems that are secure and interoperable and that can support the inclusive delivery of and access to public and private services across society(OECD, 2024) (Examples: Digid; Mijnoverheid; Telecomnetwerken; Data Centers)

"**Definition of Digital commons":** "a shared virtual realm where digital knowledge, information, and assets are managed collectively by a community", where the idea is that users have access to the information and the ability to contribute to these resources and communal democratic governance is encouraged. (Examples: Wikipedia)

So, an example for combining these two is "OpenStreetMap", which is a digital platform that provides geographic data, through maps for open use while being governed by volunteers.

Introduction:

1. Could you briefly introduce yourself?
    a. Age Range
    b. Gender (M/F/Other or prefer not to say)
    c. Highest attained education level

d. Job, job role, job function student
e. Tenure in industry and organization

Main Interview:

1. Can you describe your general experience with digital public infrastructure platforms in your daily life?

2. What factors are important to you when deciding to use digital public infrastructure platforms? *Elaborate Governance*
    a. Do your reasons for using the digital public infrastructure platforms for general use differ from those for actively participating in its governance? Please elaborate if so.

3. Can you share an example of a digital public infrastructure platform that you find particularly easy to use? What makes it that way?

4. What are the challenges that you experience while using digital public infrastructure platforms?

5. Can you tell me about a time you tried to use a new digital public infrastructure platforms platform? What was that experience like for you?

6. How do digital public infrastructure platforms help you solve challenges in your daily life? Can you provide an example?

7. How do social factors, such as family or friends, influence your use of digital public infrastructure platforms?

8. What types of assistance would you expect when using digital public infrastructure platforms?

9. In your opinion, what role should users play in the ongoing improvement and development of digital public infrastructure platforms?

Repeat Definition of Digital Commons and examples

10. How would digital commons affect your willingness to use public infrastructure compared to government or company platforms, if so, why?

11. If you were in charge of designing a digital public infrastructure platform, what would it look like?

Closing:

12. Is there anything else you would like to add?

13. Summarizing the interview and asking if the interviewee agrees

Well, that was the end of the interview! I would like to thank you for your participation in this research and hope you enjoyed the interview. Feel free to reach out to me if you have any more questions.

General Follow-up questions examples for during the interview:

- Can you explain that further?
- Can you provide an example?
- What do you mean by that?
- Can you walk me through that experience?

Appendix B: Expert interview guide

Organizations interview:

Expert interview guide

Hello, my name is Alvin, and I am researching the citizen adoption of digital public infrastructure and how organizations can deal with these challenges.

After having conducted the citizen interviews, I now would like to ask you today about how in your professional experience in public infrastructure digital common twins can deal with these challenges.

I would like to ask you for your consent to record this interview so the anonymized interview transcript can be used for analysis purposes.

Hand them their consent form

Is that okay?

Feel free to ask me any questions during the interview!

***Start Recording* (Including back-up device)**

Introduction question:

1. Could you briefly introduce yourself?
    a. Age Range
    b. Gender (M/F/Other or prefer not to say)
    c. What does your organization do with public infrastructure digital commons
    d. Role within the organization
    e. Tenure

Main interview:

Dimension 1 Data management:

1. What specific strategies and measures are you implementing to ensure user privacy is maintained throughout the platform?
2. Can you describe the concrete security protocols and processes you have established to safeguard data integrity and confidentiality?

Dimension 2 User challenges:

3. What strategies are you using to make sure information is clear and understandable for all user segments?

4. What strategies are you using to make the processes easy and intuitive to use for citizens?

5. How are you enhancing the visual design and user interface of the platform to ensure citizens like it?

6. How will you ensure that the platform provides adequate and effective assistance to users?

Dimension 3 Organizational challenges:

7. What actions are you taking to ensure digital volunteers possess the necessary skills to perform the tasks needed to run the digital common?

8. What structural and organizational changes do you implement to professionalize and formalize the digital volunteer workforce?

9. What conflict resolution mechanisms are in place to address disagreements among volunteers effectively?

10. What practices and mechanisms are in place to demonstrate transparency within the organization?

Dimension 4 Participation challenges:

11. What strategies and measures are implemented to motivate users to provide ongoing, constructive feedback?

12. How do you systematically analyze and incorporate user feedback?

13. How do you ensure citizens feel that they have an impact on the operations and impact of the public infrastructure digital common?

Dimension 5 Social and inclusive delivery:

14. What strategies and actions are to be implemented to ensure accessibility for all regardless of their background?

15. How are you actively fostering community engagement and social cohesion through the digital common?

16. What strategies and actions are you using to ensure that the platform would serve the needs of the users and help them solve challenges?

Closing:

17. Are there any other practices that you think are relevant to enhancing citizen adoption of public infrastructure digital commons and if so, why?

Well, that was the end! I would like to thank you for your participation in this research, and I hope you enjoyed it. Feel free to reach out to me if you have any more questions.

Appendix C: Gioia structure of the data