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Digital transformation of policy making: the promises of Digital Twins

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Abstract

This thesis broadly explores the influence of digital technologies on policymaking in a fast-evolving environment, focusing on the Digital Twin. Chapter 1 delves into the definitions and challenges of policymaking in a fast-evolving environment, discussing its complexity, multilevel governance, and the significance of participatory policymaking and participation. Chapter 2 links the connection between Information and Communication Technology (ICT) and its role in enhancing participatory policymaking and public involvement. It examines the functions, challenges, and promises that ICT brings into policy-making domains. In Chapter 3, the focus shifts to the emergence in the European debate of Digital Twin technologies, exploring its potential, comparative advantages, and challenges in urban planning. The subsequent chapters offer a reflection on three case studies substantiating theoretical discussions and conclude with a comprehensive summation of the insights gained. Ultimately, the research aims to understand whether Digital Twin technology is a game-changer in policymaking or only a marketing slogan.

Keywords: Participatory Policy making, Fast-evolving environment, Participation in policy making, ICT, Digital Twin

Abstract in italiano

Questa tesi esplora l'influenza delle tecnologie digitali sulla formulazione delle politiche in un ambiente in rapida evoluzione, concentrandosi su Digital Twin. Il Capitolo 1 approfondisce le definizioni e le sfide della formulazione delle politiche in un ambiente in rapida evoluzione, discutendone la complessità, la governance multilivello e l'importanza della partecipazione nella formulazione delle politiche. Il Capitolo 2 collega la connessione tra le Tecnologie dell'Informazione e della Comunicazione (ICT) e il suo ruolo nel migliorare la partecipazione nella formulazione delle politiche e il coinvolgimento dei cittadini. Esamina le funzioni, le sfide e le promesse che l'ICT destina ai domini della formulazione delle politiche. Nel Capitolo 3, l'attenzione si sposta sul dibattito nel panorama europeo delle tecnologie Digital Twin; si esplora il suo potenziale, i vantaggi comparativi e le sfide nell'urbanistica. I capitoli successivi offrono una riflessione su tre casi di studio che sostanziano le discussioni teoriche e si concludono con un riassunto completo delle intuizioni acquisite. In definitiva, la ricerca mira a capire se la tecnologia Digital Twin rappresenta un cambiamento radicale nella formulazione delle politiche o è solo uno slogan di marketing.

Parole chiave: Policy making partecipativo, Ambienti in rapida evoluzione, Partecipazione e policy making, ICT, Digital Twin

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در ماورای ماورای ما، در ماورای بودن ما و نبودن ما، آنجا دشتیست...

فرا تر از همه تصورات راست و چپ، تو را آنجا خواهیم دید. (مولانا)

Translation: There exists a field, beyond all notions of right and wrong. I will meet you there.

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Chapter 1. Policy making in a fast-evolving environment.

This chapter deals with a comprehensive examination of policy making in an environment characterized by rapid changes. It begins with Section 1.1, where the concepts of "policy making" and "fast-evolving environment" are briefly defined. Next sets the stage for Section 1.1.1, where various models of policy making are discussed, offering insight into the diverse strategies in policy making. Section 1.1.2 delves into the potential challenges met during the policymaking process, providing an understanding of the potential barriers in this endeavor. Next, Section 1.2 highlights the complexity inherent in policy making, illustrating the intricate nature of this process. The next segment is followed by Section 1.3, which navigates the concept of multilevel governance in policymaking, outlining how decision-making occurs across different layers of authority. Section 1.4 introduces the concept of participatory policymaking, which actively involves many stakeholders in the policy-making process. Finally, Section 1.5 further explores the role of participation in policy making, including examining its benefits and challenges, thereby supplying a balanced view of this approach.

1.1 Policy making in a fast-evolving environment.

“The fast-evolving environment embodies a society rapidly integrating and progressing with the advent of cutting-edge technology in fields ranging from communication to health, education, energy, and transportation. This environment is dynamic, regularly influenced by technological innovation or disruption, precipitating substantial alterations in its conditions, attributes, and dynamics. Consequently, it necessitates consistent learning, adaptability, and creativity from its constituents, whether individuals, organizations, or communities.” (Atzori et al., 2017) However, this expeditious evolution has its complications.

Picture 1. An abstract of policy making in a “fast-evolving environment “. Source: drawn by the author.



Global challenges such as climate change, economic inequality, and the ongoing pandemic underline the urgent need for swift and decisive action. In an era marked by the rapid pace of change and the increasing interconnectivity of global systems, our

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capacity to respond quickly to these challenges is tested more than ever. Thus, our role within this fast-evolving environment extends beyond mere adaptation; it necessitates proactive engagement and accelerated responses to these global threats, leveraging the technological advancements that have defined our era.

Change is a significant part of our lives, affecting various sectors, such as communication, education, and healthcare (Miah and Omar, 2012). Hogwood and Gunn (1984), as quoted by Potucek and Vass (2003), described policy in the following characteristics view: policy consists of multiple decisions, making it distinct from a single 'decision'; this distinction arises from the fact that policymaking involves an ongoing and comprehensive process, whereas decision-making refers to choosing among competing alternatives at a specific time and encompasses both actions and intentions, setting it apart from a goal, which only represents a desire to achieve a particular future outcome without necessarily involving the necessary measures for its realization. So, for example, if a government aims to implement a specific action responding to a complete goal, it should create a policy outlining and authorizing the steps required to achieve that goal. "*Policy refers to the actions taken by a government in response to specific issues, such as taxation, housing, etc.*" Also, the policy includes what the government is actively addressing concerning a particular matter. In some cases, if the government ignores a concern, it essentially means their policy is to take no action (Anderson, 1997). According to Clarke and Cochran (2010), as quoted by Birkland (2019), the policy is the outcome of the struggle in government over "who gets what". Peters (2010) said more simply that policy is whatever acting directly or through agents, as it influences the life of citizens.

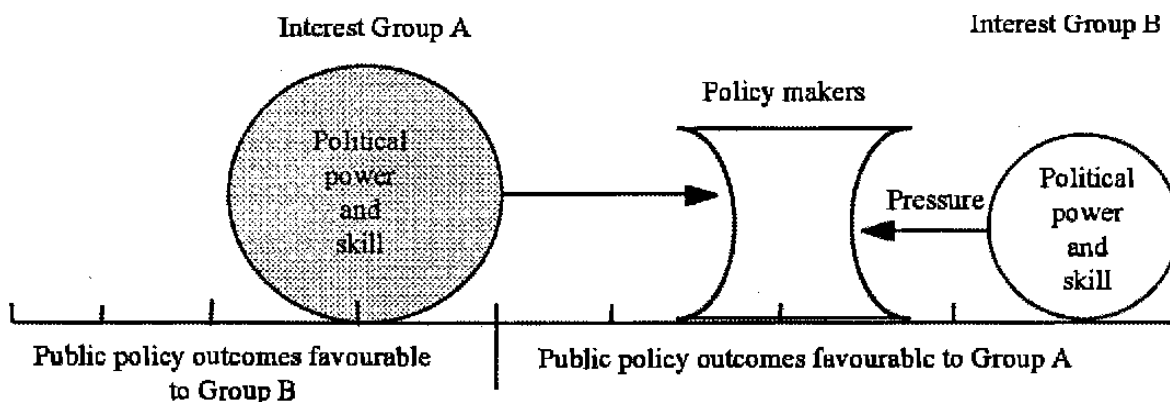
Furthermore, policymaking is made in response to some problem that deserves some government response and is made in the "public interest" (a term enclosed in quotation marks because not everyone will agree on the public interest); The process of creating and executing policies is undertaken by both public and private stakeholders, each of whom has their unique motivations which as a result, they will perceive and understand the issues and their possible solutions in different ways; policymaking is oriented toward a goal or desired state, such as reducing the incidence (Birkland , 2019). The policy is the difficulty of some problem or the government's decision (Howlett et al., 2009, as quoted by Birkland, 2019). According to Woll (1974), classical, group, elite, and systems models have been developed to explain how the policymaking process progresses.

A) The classical model: The classical or institutional model, as described by Hanekom (1991), emphasizes the importance of considering the interests of the legislative, executive, and judicial branches before developing and implementing policy (Woll, 1974). Although it acknowledges the legislature's primary role in policymaking, it also stresses the shared responsibility among all three branches of government. However, Henry

(1992) argues that this model, focusing on the government's organizational structure, overlooks the connections between the branches, isolating them from one another.

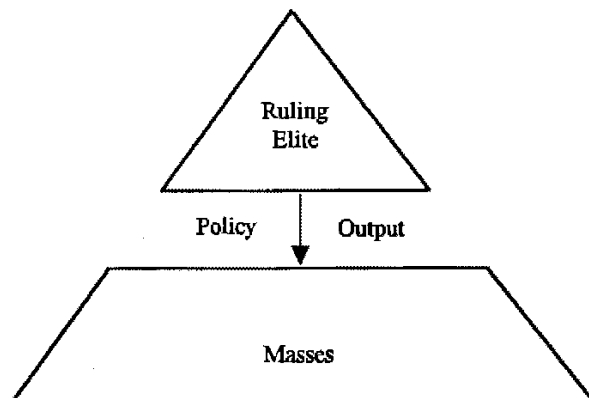
B) **The group model:** Dye (1978) suggests that, in group theory, policymakers are constantly influenced by various competing groups. The policy is seen as a balance achieved through the struggle among these groups at any given time. As different interest groups have distinct concerns, they exert pressure on one another to influence policymaking (Henry, 1992). As a result, public policy outcomes often favour the group with the most decisive influence (Hanekom, 1991).

Figure 1. This figure shows how the group with the most substantial influence impacts policymakers. (Source: Henry, 1992)



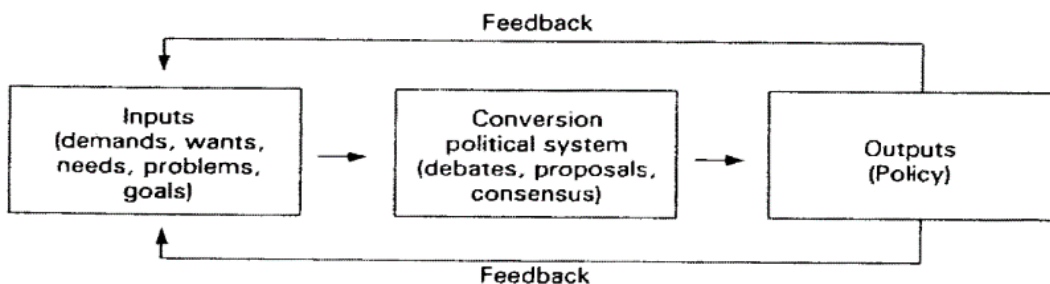
C) **The elite/mass model:** In the elite/mass model, society is divided into two categories for policymaking: a small group of elites who are leaders and a larger group of masses who are followers (Woll, 1974). Presumed to be well-informed, the elite model creates policies for the masses, who are less informed. As a result, public policy reflects the preferences of the elite (Dye 1978, as quoted by Hagland, 2023). The elite share common values that distinguish them from the masses and public officials are tasked with implementing policies from the elite and directed towards the masses (Henry 1992, as quoted by Henry 2015).

Figure 2. The Elite/Mass model (source: Henry, 1992 retrieved from Coning and Bierman, 1995)



D) **The systems model:** The systems model views policymaking as a system consisting of critical subsystems encompassing inputs, conversion, outputs, and feedback (Fox et al., 1991, as quoted by Orozco, 2019). In the systems model, the environment generates policy inputs, including demands, wants, needs, problems, and goals channeled into the broader political system. The political system transforms these inputs into policy outputs through discussions, proposals, and consensus-building. Public policy is depicted as an output of the political system (Dye, 1978, as quoted by Hagland, 2023).

Figure 3. The Systems Model. (Source: Hanekom, 1987)



Policymaking in fast-evolving environments faces several challenges, such as when policymakers struggle to keep up with the rapid pace of technological change, creating our world (Schneier, 2019). Rapid policy expansion can appear in fast-evolving, uncertain, and contested policy arenas as the reasons for making policy are unclear (Saad-Sulonen and Horelli, 2020). It is essential to know that policies can fail when complex problems are addressed and are expected to control as fast as technologies grow (Mueller, 2020). The policy can be characterized by open study into all aspects of society to avoid becoming marginalized or a tool that leads to emptiness (Galster, 1996). Policymaking in fast-evolving environments presents several challenges (OECD, 2011).

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Such as the need for open questions about all aspects of social issues (Galster, 1996). Identifying the right combination of regulations, policies, organizational structures, and skills is needed to create transparency and accountability; additionally, the need to have qualities such as flexibility, adaptability, and the ability to respond quickly to changing circumstances (Burrowes and Shannon, 2021).

To better understand and address the challenges presented by fast-evolving environments, it is essential to adopt innovative and adaptive approaches that reflect these environments' complex and interconnected nature (Prothi et al., 2023). This fast-evolving environment requires policymakers to continuously learn and collaborate with stakeholders, including experts in various fields, industry representatives, and community members, to ensure that policies are informed by the latest knowledge and best practices (Schlaile and Urmetzer, 2019).

Furthermore, anticipation tactics and scenario planning can help policymakers prepare for future developments, reducing the risks of policy failure (Muiderman et al., 2020). Embracing digital tools and data-driven approaches in the policy process can also help policymakers navigate the uncertainties of fast-evolving environments (Gordon, 2022). Artificial intelligence (AI) in policy analysis and evaluation can supply valuable insights for decision-making and facilitate the development of more targeted and effective policies (Patel et al., 2021)

Additionally, implementing e-governance and online participatory platforms can increase transparency and help inclusive policy discussions, leading to more robust and legitimate policies (Baxter, 2017). Nevertheless, it should also be aware of potential hazards and ethical considerations associated with using recent technologies and data-driven approaches (Harrison and Reyes, 2022).

Issues such as data privacy, algorithmic bias, and the digital divide should be carefully considered and addressed to ensure that policies do not inadvertently exacerbate existing inequalities or create new problems; by remaining vigilant and adopting a proactive stance towards these challenges, it is possible to control the potential of technological advancements to create more effective and responsive policies in fast-evolving environments (New and Castro, 2018).

1.2. The complexity of policy making

The environments are changing so fast, and “what we, as a society, are facing is a riddle of **challenges arising from technological progress** that requires us to adapt; we are living

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in a world that changes rapidly and presents us with complex challenges stemming from technological advancement that we need to adapt to (Fri and Ansolabehere, 2012).

Figure 4. Showing how complexity can be modified by policy making. Source: <https://www.businessillustrator.com/complexity-and-policy-making-cartoon-summary/#>



In this advanced society, infrastructure significantly affects the environment and economy (Palei, 2014). The economy evolves, constantly creating and discarding industries, technologies, and occupations based on numerous factors like technology, policies, and international competition (Carlsson, 1989, as quoted by Carree et al., 2002). Making policies gets more complicated due to the interconnection of sectors in a quickly changing environment; we need to balance technological advancements, economic growth, and environmental impacts (Kirschke et al., 2017). Policy experimentation and adaptive governance become essential for managing policy complexities in such an environment. Governments should adopt iterative and experimental approaches to policymaking, allowing for constant evaluation and adjustment (Huitema et al., 2018). According to Concilio et al. (2019), "These approaches include three primary cycles: design, implementation, and evaluation; these cycles are strongly interdependent, and this is at the core of the experimental dimension of policymaking that intends to implement. The policy design cycle is focused on highlighting the existence of a joint problem, mobilizing a set of goals and objectives concerning it, and defining policy strategies and actions as attempts to contribute to solving the problem; the policy implementation cycle gives form to the policy, delivering it to the public ". Policymakers should enhance the adaptive capacity of systems to respond and recover from

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disturbances (Swanson and Bhadwal, 2009). Navigating policymaking complexities in a fast-changing environment requires embracing uncertainty, fostering innovation, and building flexibility (Tõnurist and Hanson, 2020). The policy is a complex, interconnected, and evolving problem, like a complicated puzzle, with each piece representing a different contributing factor (Johal et al., 2022). Coglianesi et al. (2021) suggests evaluating all aspects to understand the issue's structure, and practical approaches to address complexity should be developed by understanding the interdependencies of these factors.

One approach to addressing the complexity of policymaking is to use policymaking models; policymaking models are frameworks that supply a systematic way of understanding the policymaking process; there are several commonly used policymaking models, including the institutionalism model, the incrementalism model, and the advocacy model (Hahn, 2023). Another approach to addressing the complexity of policymaking is to use innovation and diffusion models; innovation and diffusion models are frameworks that provide a systematic way of understanding how policies are developed and implemented. These models focus on the process of policymaking, from the identification of a problem to the evaluation of policy outcomes (Sabatier, 2023). Policymaking models simplify the policymaking process and do not capture the full complexity of policymaking; therefore, one should be aware of using them to inform policymaking decisions rather than relying on them as a definitive guide to policymaking (Khan, 2023).

Big data analytics is another approach to addressing the complexity of policymaking; big data analytics involves the use of large datasets to identify patterns and trends that can inform policymaking decisions; big data analytics can provide policymakers with real-time data and analysis that can inform decision-making, leading to improved efficiency and accuracy (European Commission, 2016). According to Concilio et al. (2019), "big data can help in two ways: firstly, it helps to get past the usual delays in finding information that faces with traditional data sources, and secondly, it uses the widespread presence of digital devices and mobile networks to gather data from everywhere". These issues differ significantly from those associated with evidence-based approaches in policymaking, which are strictly tied to dependable and seen procedures that ensure the *credibility of evidence* (Concilio and Pucci, 2021). In sum, navigating the complexities of policymaking requires decision-makers to acknowledge the constraints inherent in policymaking frameworks. It is also crucial for them to understand and address the difficulties of introducing recent technologies like big data analytics.

In fast-evolving environments, the escalating pace of change necessitates prompt and adaptive responses, specifically in policymaking. Traditional legislative processes, which can be lengthy

and inflexible, often need to be revised in the face of such rapid evolution. To respond effectively, it becomes crucial to maintain an experimental mode in policymaking, envisaging it as a continual, adaptable learning process. This innovative approach enables policymakers to exploit the benefits of technological advancements while simultaneously managing and mitigating the associated risks. It promotes flexibility and responsiveness, critical components in successfully navigating our rapidly changing landscapes. Thus, it is clear that in the accelerating tempo of our world, experimental policymaking becomes a critical factor, allowing us to harness change rather than being overwhelmed by

1.3. The multilevel governance of policymaking

“Governance is about the ability to rule and achieve collective public action without relying solely on state authority” (Krahmann, 2003). Multi-level governance (can be likened to a complex web of interconnected systems, with each strand standing for a different level of government authority; the emergence of multi-level governance¹ is a response to the growing complexity of societal issues that often cross traditional boundaries and require coordination and cooperation among various levels of government (Sørensen and Torfing, 2011). Critically, multi-level governance captures the structures and processes of governing, much like a spider web captures the intricate design and function of its strands; the system of multi-level governance is characterized by the distribution of power among different layers of territorial units, ranging from local to regional, national, continental, and global, the governance process involves defining and pursuing collective interests, which requires some degree of exchange between the state and society. (Pierre and Peters, 2000).

Governance primarily concerns coordinating public and private actions and resources to achieve a common goal rather than being centred on institutional structures; as such, effective management of multi-level governance involves integrating processes across different institutional levels to promote the interests of the system as a whole; however, institutions remain critical to multi-level governance, as they define the linkages between different levels of government and help coordinate administration across those levels, additionally, institutional webs in which power is embedded shape and constrain political action (March and Olsen, 1989).

¹ MLG: Multi-level governance

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Picture 2. An abstract of multilevel governance of policy making. Source: drawn by the author



The structure of multi-level governance varies in power distribution, the degree of institutionalization, and coordination methods, and MLG implies exercising political authority and usually relies on executives standing for different territorial jurisdictions; at the same time, other actors and stakeholders may also play a role (Marcussen and Torfing, 2008). The authors argue that "governance networks"² are critical structures of multi-level governance (MLG) and consist of both public and private actors working together to address complex problems; within these networks, actors are held accountable to their constituencies; in addition, they could navigate power dynamics and conflicts of interest to achieve their goals. Marcussen and Torfing (2008) also note the

² **Governance networks:** refer to the collaborative relationships between different actors and organizations involved in policy making and implementation.

importance of "institutional bricolage"³, which involves the creation of new institutional arrangements by combining existing institutions in innovative ways to address new challenges which require flexibility, adaptability, and an understanding of the complex interdependencies and trade-offs involved in policymaking. Vien Kooiman (1993) characterizes governance as "*the emerging patterns of the governing activities carried out by social, political, and administrative actors.*" According to Jessop (1995), governance theories focus more on social modes of coordination than political modes of organization, which are narrowly defined as bureaucratic, juridical-political, or hierarchically organized.

Based on the concept of multi-level governance and its emphasis on collaboration and coordination across various levels of government, participatory policymaking plays a critical role in addressing the complexities of contemporary societal issues; participatory policymaking involves actively engaging multiple stakeholders, including public and private actors, in decision-making (Marcussen and Torfing, 2008). By incorporating diverse perspectives and abilities, this approach promotes more inclusive, context-sensitive, and innovative solutions better equipped to tackle the complex challenges that arise in a rapidly evolving environment (Jessop, 1995). Moreover, participatory policymaking not only fosters transparency and accountability but also enhances the legitimacy of policy outcomes by ensuring that the interests and concerns of different actors are considered; as such, participatory policymaking represents a valuable component of effective governance, complementing the adaptability, flexibility, and interdependence required to navigate the complex web of multi-level governance systems (Vien Kooiman, 1993).

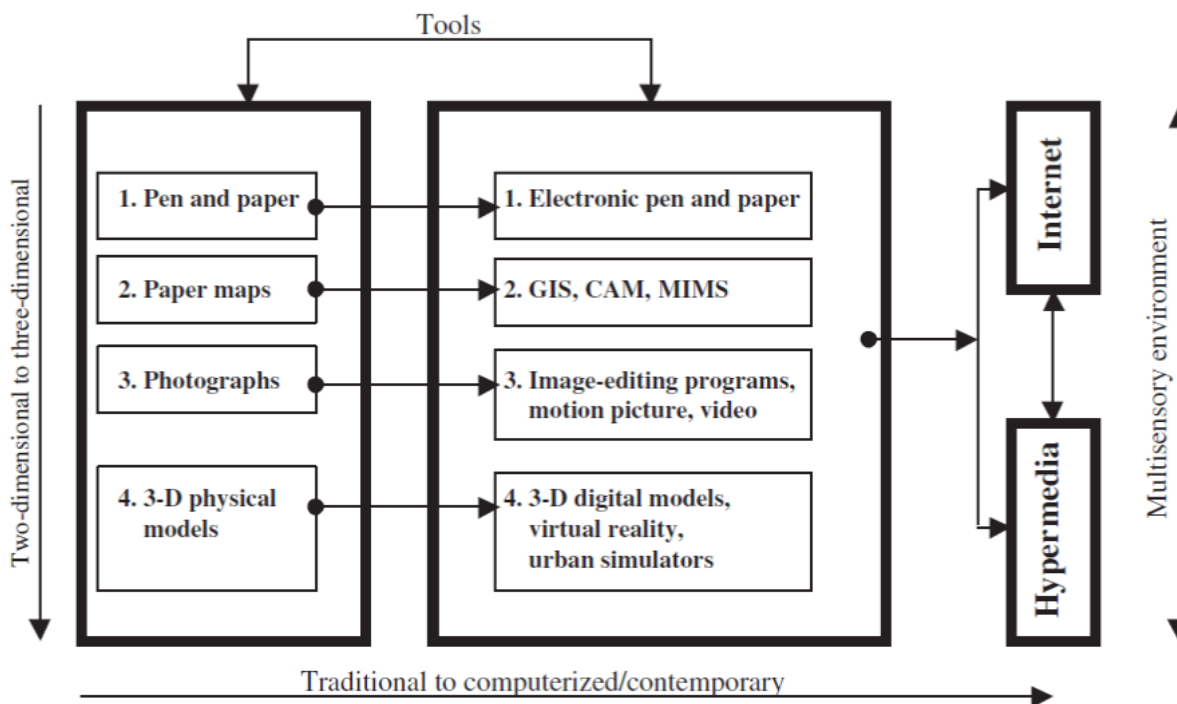
1.4. Participatory policymaking

The word "participation" has been argued based on many authors' perspectives (Masango, 2001). which describe it in these ways; Participation refers to the act of taking part in a particular activity (Webster, 1995). Participation means taking part, and when one takes part contributes to something (Vroom and Jago, 1988). Participation is "*a process through which workers share in decision-making that extends from and beyond the decisions implicit in the specific content of the functions they do*" (Orpen, 1977). Participation can be defined as "an activity undertaken by one or more individuals previously excluded from the decision-making process in conjunction with one or more other individuals who were previously the sole protagonists in that process; participation means taking part, a full part, in the micro-decisions of the day-to-day management of the production process"

³ **Institutional bricolage:** refers to the way in which actors within a governance network in a particular context use available resources, tools, and institutions to create new and innovative solutions to complex problems. For example, in Milan, the development of the city's public bike-sharing system, BikeMi, was made possible through institutional bricolage. The city government worked with private partners to design and implement the system, using existing infrastructure and resources to create a new solution to address the challenge of urban transportation.

(Patience, 2021). Finally, Butterfoss (2006) speaks of the disparities between definitions and that participation covers a broad scale, from consultation to citizen power.

Figure 5. The historical transformation of visualization techniques and tools of participation in policy making. Source: Adapted from K AL-Kodmany (2002)



Macintosh (2004) argued that the importance of participation relies on the essence of policies which are "for the people, by the people, and of the people." Participation is an approach to ease the inclusion of individuals or groups in the design of policies via consultative to achieve liability, clarity, and active citizenship (McCracken, 2010). participation in policymaking is at the heart of open government reforms. It could improve the quality of policies (OECD, 2017). Participation can be any process that directly engages the public in decision-making and considers public input in a clear structure and function; participation requires inclusive and effective representation, participative capacity among staff and participants, and an environment of integrity (OECD, 2018)

New forms of public participation are appearing as citizens seek opportunities to actively take part in shaping the policies that affect their lives; when individual citizens participate in a policymaking, they become more informed about policy issues and develop civic skills, which can also improve the quality of policies (Lee,2023). Participation supplies the opportunity for communication between agencies making decisions and the public, which can be an early warning of potential conflicts and help

build trust and understanding between the public and decision-makers (Department of Conservation, 2009). Considering the diverse nature of participation in theory and application, the primary requirement for any participatory activity is to understand its aim clearly. There is a need to ask why to engage in this process and what the objective is to conduct in the short and long term. The difficulties within the idea of participation have been emphasized previously that there is no one-size-fits-all model to follow. Instead, the method or degree of involvement should align with the context and purpose. 'Arnstein's Ladder of Citizen Participation' can serve as a valuable tool in clarifying these goals (Arnstein, 1969).

In this part, questions are raised about the motivations and capabilities of individuals and organizations to engage citizens. For instance, three questions could be asked at the partnership level: Is citizen opinion considered? Is citizen perspective included in the decision-making process? Is it a policy mandate to properly consider citizens' views in decision-making? The answers to these questions provide insight into what can be done and what needs to change. The aim of supplying guidance is to evaluate participation methods. The best way that has drawn much attention to it is the "Arnstein's Ladder of Citizen Participation", which consists of eight steps, divided into three categories: A) Non-participation; i) Manipulation: Authorities use citizens for their own goals without genuinely involving them in decision-making. ii) Therapy: Citizens are involved, but their input needs to be considered, and they are not genuinely empowered. B) Tokenism; i) Informing: Citizens receive information about policy decisions, but there must be a direct feedback channel. ii) Consultation: Citizens' opinions are taken, but there is no guarantee that they will be used or directly impact the decision-making process. iii) Placation: A few citizens are given a voice in policymaking, but the decision-making power stays with the authorities. C) Citizen Power; i) Partnership: Citizens and authorities share decision-making power, with the potential for negotiations and influence on policy decisions. ii) Delegated Power: Citizens are given significant decision-making authority, and authorities function as collaborators or advisors. iii) Citizen Control: Citizens have complete control over policymaking, with the power to make decisions and give resources. The importance of participation is to see participation as not just an end but the end of effecting lasting change. The role of participation is to move from being consultation-focused to participation-focused (Ruth Sinclair, 2004). Then there is a need to start to build a culture of participation. (OECD, 2016).

Participatory policymaking, as discussed by Baccaro and Papadakis (2019), refers to an inclusive approach to decision-making that actively involves various stakeholders in the formulation, implementation, and evaluation of policies; this process aims to increase democratic legitimacy and ensure that the voices and needs of diverse groups are considered, leading to more effective and equitable policy outcomes, while participatory

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policymaking holds great promise for more inclusive governance, it also faces challenges such as unequal power dynamics, the risk of tokenism, and the potential for co-optation by dominant interests; therefore, it is crucial to navigate these hazards and develop strategies that facilitate meaningful engagement to reap the benefits of participatory policymaking. Participatory policymaking is a mechanism of connection and collective struggle; its practice lacks an operational foundation and, on the other hand, gives a community surveillance power on matters that directly affect it (Kamau and Khsiebi, 2022). According to Locke et al. (1986), the accomplishment of participatory policymaking depends on understanding both the motivational and cognitive mechanisms that influence it; motivational factors include trust, control, ego involvement, identification with the organization, group support, and goal setting; on the other hand, cognitive factors encompass upward communication, effective use of information, and employees' comprehension of the organization rationale. Giummarra et al. (2022) argue that participatory policymaking requires purposeful strategies that find meaningful preferences (e.g., where, when, how, and with whom) and support building capacity or enabling ongoing participation.

Participatory policymaking can help citizens overcome the feeling of powerlessness and develop a sense of community as a strong bond (Midgley, 1986). Furthermore, it should be understood as the active involvement in making and implementing policy at all levels and in all political and socioeconomic activity (Lisk, 1988). It is activated by complex problems which cannot fully comprehend the complexity and nuances of issues alone. The inputs of diverse stakeholders can be invaluable in identifying relevant variables, defining the scope of problems, and finding solutions (Ansell and Gash, 2008). Olujimi and Egunjobi (1991) and Burke (1983) define participatory as the ultimate voice in policymaking as "an activity" which enables people to have an input in the policymaking process and to play a role in improving the quality of policy; however, the question is, could participatory policymaking and participation act as leverage to make equilibrium in a society where everyone can have a well-sufficient life?

Most citizens cannot determine how well their government works because they are just citizens, not government members (Halachmi and Holzer, 2010). When participatory policymaking is conducted in a structured and well-informed manner, it can play a role in achieving better outcomes which helps find the interests and concerns of different participatory policymaking and build consensus and ownership around policymaking (Fischer and Black, 2018). According to Evans and Graham (1975), "participatory" is often categorized using dichotomies such as "weak" versus "solid" or "superficial" versus "deep", which carry inherent value judgments, suggesting that participatory lacking in policymaking power is inferior to more local forms of participation; however, the author means that neither extreme is optimal, instead advocates for a middle ground that

integrates elements from both top-down and bottom-up approaches. "There is a critical difference between going through the empty tradition of participatory policymaking and having the real power needed to affect the outcomes of the process "(Arnstein, 1969). "Basically, the fact that calls for public involvement haven't led to real social changes, and that the affluent still control the decision-making process, implies that the push for more participation might just be a 'populist red herring.' This means it's likely a distraction that sounds good to the public but doesn't actually achieve much." (See also Robinson 1993; Beatley et al. 1994)

1.4.1. Benefits and challenges.

Ank Michels and Laurens De Graaf (2010) argued that participation has several benefits for citizens; the first is the educative: citizens may increase their civic skills and become more competent if they participate in public policymaking; a second benefit of Participation is integrative. Participation contributes to citizens' feeling of being public citizens, part of their community; consequently, they may also feel more responsible personally for public decisions, and thirdly, participation contributes to greater legitimacy of decisions. As Rousseau (1762) argued, participation is crucial in producing good rules. Citizen participation is a little like eating spinach: no one is against it in principle because it is good for you (Arnstein, 1969). The Core principles of public Participation in policymaking argued in this way that citizens should get a guarantee that the public's input will impact, all participants' requirements are met, and their interests are communicated; the approach actively seeks out and encourages the engagement of individuals who may be affected and choose how they will participate and should give the knowledge of how their comments influenced in the policy (Creighton, J. L., 2005).

There are gradations of participation regarding the degree of power or control participants can exercise to shape the outcome (Arnstein, 1969). Bughin et al. (2018) also regarded power as the central variable; they argued that power distribution would determine the fairness of a given process because power imbalances create persistent patterns of unequal access. According to Biggs (1989), participation is the expectation that citizens have a voice in policy choices; such participation takes many forms, from community meetings to citizen advisory committees, administrative law and, more recently, the idea of citizens as clients; Whatever the state, though, the concept of participation rests always on a sharing of power between the governed and the government; so somewhere between policymaking by administrative and direct democracy lies the terrain for Participation. Kaba (2000-2001) argued that it is not about reflecting on the question, "Why participation at all? "This does not question the value of

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Participation as a means of gaining a "voice "; instead, people should be included at the table. Participation stimulates the exchange and integration of information (Stasser and Titus, 1987). It reduces resistance to change and helps members' commitment (King et al., 1992). Participation fosters learning by acquiring, sharing, and combining knowledge (Edmondson, 1999). In policymaking it enables citizens to remove obstacles to effective performance, reducing frustration and strain (Huitema et al., 2018). In policymaking it enhances the quality of policy and promotes clearness and answerability (Rowe and Frewer, 2000).

Similarly, Arnstein (1969) highlights the importance of participation to empower citizens and decentralize power imbalances in policymaking. She argues that participation requires a redistribution of power, enabling citizens to influence and shape policies. In the same, Vein et al. (1987) emphasizes the importance of participation in policymaking, especially those most affected by the policy; they suggest that such participation can help reduce conflict and increase the legitimacy and acceptability of policies. Fung and Wright (2003) assert that participation can also promote the values of deliberation and dialogue, which can contribute to better policy outcomes. Green and Schwam-Baird (2015) argue that Participation is not driven by the hope for specific results but rather by the desire to fulfil the responsibility to take part; encouraging such a perspective among the public could aid in supporting the practice of public participation. Abels (2007) argues that the participation of citizens in policymaking leads to a shift in the distribution of roles and power between politicians and citizens. Unfortunately, there is a lack of understanding of the true impact of citizens in participatory policymaking processes. "A significant problem of all citizen participation models is legitimizing citizen recommendations vis-a-vis competing claims by interest groups and elected or appointed policymakers; in any democratic system, legitimation of power is linked with due process and, ultimately, public approval through elections "(Almond and Verba, 1963). Citizen participation should be an integral part of this process, but not replace it; in the absence of a culture that does encourage citizens to participate actively, participation culture is considered a principle or an attitude that each person should have (Adeshina and Ojo, 2012).

In contrast, public participation was neither "encouraged" nor "discouraged "and has not even been considered a "norm "(Pillay, 2012). Inadequate information: the success of a participation program depends on people having a minimum level of awareness and knowledge (Macintosh, 2004). Conflicting sectoral interests: Individuals generally show less interest in participating in activities that do not align with their interests or are not expected to impact them directly (Michels and De Graaf, 2010). Unfavorable attitudes

towards participation, the public may believe that participation is only effective, and that the government is only responsive. Keef, S.P. (1991). According to Barnes (2019), "*The difficulties include many factors that can impact public engagement, such as the lack of trust in government, which causes hesitancy among citizens to participate or, as is said before, access to limited information for particular communities, primarily low-income and minority communities, or low levels of civic engagement, which may lead to lower voter turnout, particularly affecting low-income and minority communities; also, immigrants may face cultural and language barriers that prevent them from participating in communities, while some people may need more financial resources such as access to transportation or childcare to participate.*" Cost is a significant obstacle argued by Bovaird and Löffler (2003) that often needs to be addressed in discussions on the usefulness of public engagement; however, even if the time costs of the citizen participants are ignored, the low end of the per decision cost of public participation groups is arguably more expensive than the policymaking of a single administrator and the expenses discussed are neither adjusted for the social capital value that participating citizens get from doing nor are they considered for the possibility of more effective policy engagement. Conrad and Hilchey (2011) argued that other obstacles that are important to consider are: i) unequal representation of voices and interests, with certain groups either silenced or marginalized; ii) limited resources, such as time and money, which may only be available to some interested parties; iii) unproductive conversations can lead public participation to useless conversations and debates due to various opinions, interests, and perspectives; iv) unintended consequences can lead public participation to unintended consequences, such as unforeseen economic or social impacts. Fung et al. (2003) notes that participation faces significant political obstacles, including low voting turnout and disagreements about the role of non-electoral public participation in contemporary democratic institutions, which political challenges could lead to government decisions and social actions that could affect marginalized and ordinary people.

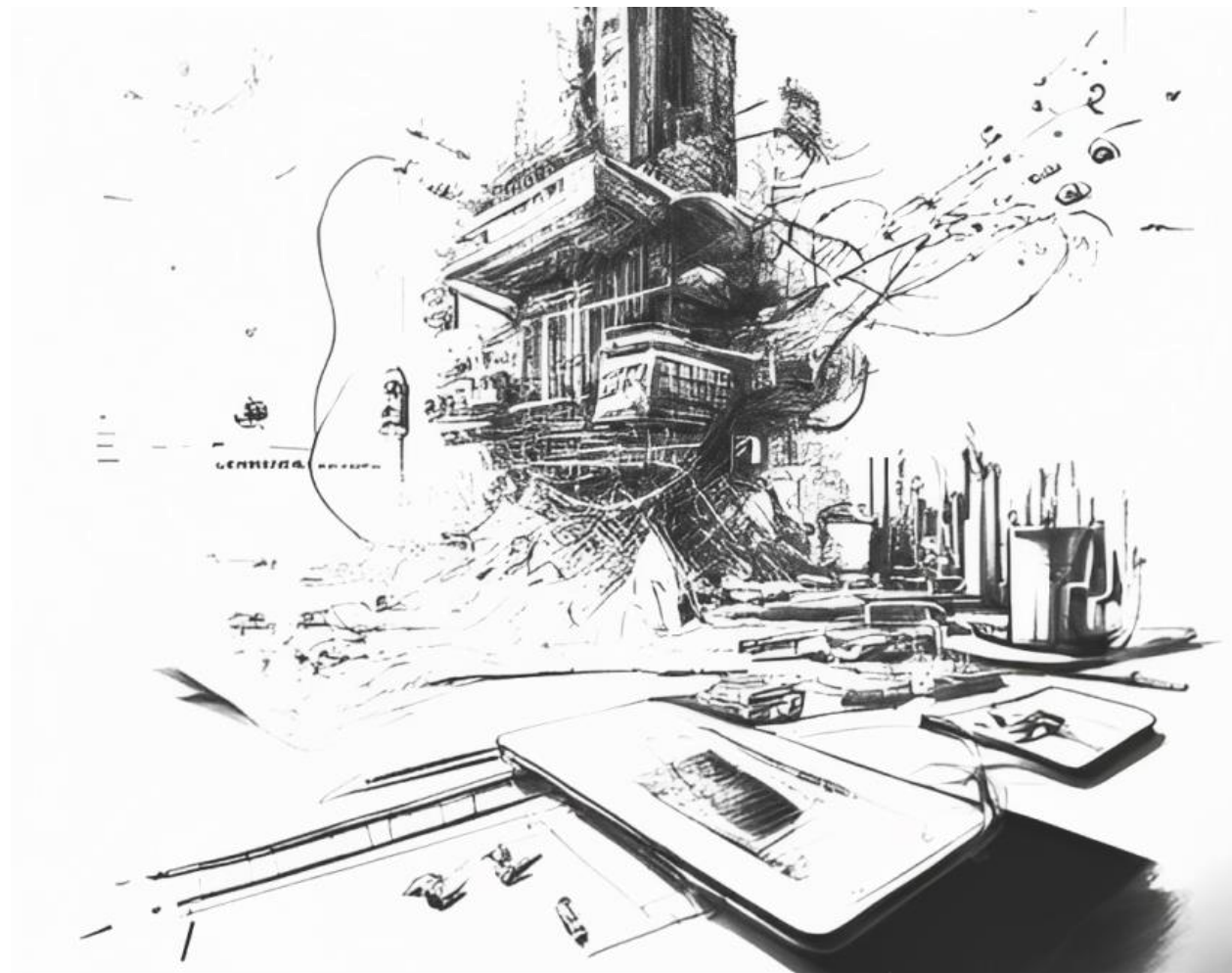
Chapter 2. ICT and its role in participatory policy making.

Chapter 2 delves into the significant role of Information and Communication Technology (ICT) and its connection to participation in policy making. Section 2.1 starts the discussion by mapping the linkage between ICT and participation in policy making, providing an understanding of how these concepts connect. Then, it sets the stage for Section 2.2, which explores the role of ICT in policy making, offering an in-depth examination of how technology impacts and shapes the policy formulation process. Moving forward, Section 2.2.2 discusses the functions of ICT across various domains, illustrating the widespread influence of technology in different spheres of policymaking. The last section, 2.2.1, navigates the challenges and opportunities of ICT in policy making, providing a balanced perspective on the potential advantages and difficulties of using ICT in this context.

2.1. The functions of ICT across various domains

Information and Communication Technology (ICT) serves various functions across domains such as education, healthcare, business, governance, and communication. Some of the critical tasks of ICT have been collected in the following dialogue. ICT enables efficient and effective communication through email, instant messaging, video conferencing, and social media platforms, facilitating real-time interaction and collaboration among individuals and organizations (Fuchs, 2017). In Informational access and storage, ICT provides access to vast amounts of information through search engines, online databases, and digital libraries; additionally, it allows for the storage of large volumes of data on local and cloud-based servers, making information easily retrievable and shareable (Alkhater et al., 2018).

Picture 3. An abstract of "ICT and its role in participatory policy making". Source: drawn by the author.



"Information and Communication Technology (ICT) has far-reaching impacts across various domains, not limited to e-learning. Its influence spans from the education sector, where it facilitates the creation and dissemination of content through online platforms and courses, and promotes distance learning and lifelong education (Bates, 2019). In terms of teamwork and collaboration, ICT empowers geographically dispersed teams to work cohesively using project management software, shared documents, and virtual workspaces, thereby increasing efficiency and productivity (Turban et al., 2018). ICT's role is equally significant in the automation of tasks and processes, streamlining workflows and improving accuracy in sectors like manufacturing, finance, and customer service (Chui et al., 2016). Additionally, it provides organizations with advanced tools for data analysis and visualization, paving the way for data-driven decision-making, trend analysis, forecasting, and performance monitoring (Waller and Fawcett, 2013)."

In e-governance and citizen engagement, governments can use ICT to improve service delivery, enhance transparency, and promote citizen engagement through online services, public consultations, and feedback mechanisms (Dunleavy et al., 2006). In healthcare and telemedicine, ICT is crucial in improving healthcare services by enabling electronic health records, remote consultations, patient monitoring, and supporting research and development in medical fields (Wootton, 2012). Through entertainment and multimedia, ICT keeps creating, distributing, and consuming multimedia content like video, audio, and gaming, enriching users' experiences and supplying various entertainment options (Flew, 2019). Networking and social interaction, ICT allows individuals to connect and interact with others, fostering relationships and building communities through social networks and online forums (Ellison and Boyd, 2013). In conclusion, incorporating such tools in policymaking is evidence of the transformative power of ICT. They serve not only as mechanisms of democratic practice but also as the driving forces behind the evolution of policymaking processes, fostering a more inclusive, participatory approach.

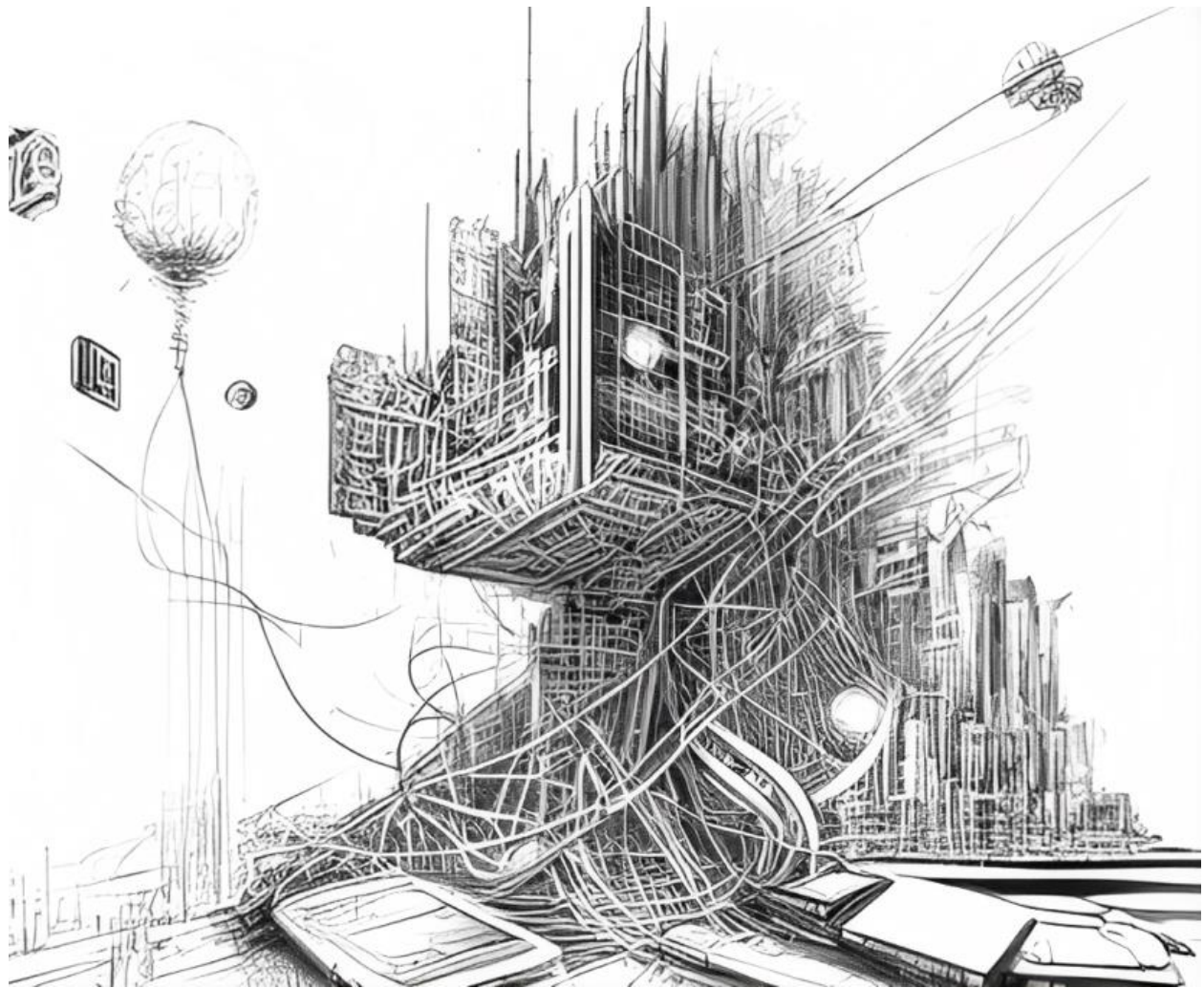
2.2. The linkage between ICT and policy making.

What challenges arise in achieving control over personal data in the digital age? What potential negative impacts could occur from using ICT in policymaking, such as overrepresenting individuals with greater access or the potential for manipulation or misinformation?

How can individuals and organizations balance the benefits and challenges of new tools and technologies, particularly in policymaking and public service provision?

Chapter 3. The emergence of new Technologies with a focus on Digital twin

Picture 4. an abstract landscape of “The linkage between ICT and policy making “. Source: drawn by the author.



In today's rapidly evolving world, participation shapes our interactions and environment. Drawing from Arnstein's (1969) perspective, participation can be compared to the fuel that powers the engagement engine, figuring out its level of activity and progress. At the same time, ICT encompasses a wide range of digital tools and technologies that ease communication and information sharing, which may give citizens both "a lot of control" and "a lot to control" (Walker, 2016). With ICT-supported participation, citizens can act as navigators by providing valuable feedback, ideas, and opinions to inform policymaking decisions, creating a more interactive and engaging policymaking experience (Simonofski et al., 2021). The connection between participation and ICT lies in their combined capacity to promote more inclusive and effective policymaking; by using ICTs, governments can facilitate broader participation, allowing citizens to offer their insights, viewpoints, and experiences to policymakers (Susha et al.,

2017). This integration can lead to more informed, evidence-based policies that better reflect the needs and aspirations of the people, resulting in more practical outcomes (Panopoulou et al., 2017).

However, a significant challenge is achieving control over personal data in the face of unpredictability in the digital and informational age (Friedewald, 2011). It is essential to trust that third parties would treat their information ethically and have some control over how that information is used. Citizens are vulnerable when confronting technology due to complexity, time constraints, and continuous partial attention, leading them to simplify their behaviour as cognitive misers (Kim and Moon, 2018). New tools and technologies are constantly emerging and transforming how we live, work, and communicate in the modern world (Lacity and Willcocks, 2014). Technological innovation is fast-tracking, leading to the development and release of new tools and technologies; for example, the Digital Twin, Artificial Intelligence (AI), the Internet of Things (IoT), and blockchain technology are constantly advancing, creating both opportunities and challenges for individuals, businesses, and governments (Sivarajah, 2017). As Bughin et al. (2018) argued, emerging tools and technologies can disrupt current industries and transform lifestyles. To stay workable, everyone must stay on top of new technological developments and adapt to them (Klingenberg, 2017). As Lacity and Willcocks (2014) note, "The speed of technological change is going faster, and it will be important to stay up with the latest developments to maintain a competitive edge in the digital age." Brynjolfsson and McAfee (2014) argued that digital technologies have driven much of the recent economic productivity growth.

Furthermore, the new tools and technologies have the potential to provide individuals and organizations with access to information and resources that were previously unavailable, which may lead to new opportunities and innovations. It is crucial to balance the benefits and challenges of new tools and technologies (Brynjolfsson and McAfee, 2014). Information and Communication Technology (ICT) supplies new avenues for individuals to participate in policymaking, including online consultations, social media, and mobile apps (Kumar and Chander, 2020). However, according to Chadwick and Maynard (2016), there may be potential issues in using ICT to promote inclusivity in policymaking, such as the overrepresentation of individuals who have greater access and the use of ICT in policymaking may have unintended consequences or negative impacts, such as the potential for manipulation or misinformation. "It is also important to recognize that critical factors for using ICT to promote inclusivity may only apply in certain contexts. On the other hand, as technology advances rapidly, it can be difficult to learn and adapt to it at the same speed" (Smith, 2018).

ICT has simplified the policymaking process and enhanced public participation and the overall quality of public services. Traditional engagement approaches involve stimulating citizen participation in policy decisions through suggestions and indications that follow a typical top-down decision-making process; the municipality first shapes public services, and then citizens are engaged through a mix of online and off-line initiatives which collect their points of view, criticisms, and suggestions to improve the services; on the other hand ICTs and especially social media, are used to widen the number of participants in the public debate and to give a voice to individuals who are not usually willing to participate in person in public debates; however, this digital revolution does not come without challenges (Castelnovo et al., 2016). It causes a critical examination of its impact and a discussion on mitigating potential risks while expanding benefits to ensure inclusive development in the ICT-dominated era; this complicated relationship of opportunities and challenges forms the core of the debate in this section.

As Tim Berners-Lee, the inventor of the World Wide Web, stated “ it is well established that the role of ICT in policymaking has shifted the balance of power between government and citizens; the power of ICT is in its universality, which is accessible by everyone, regardless of disability”; this emergence has enabled greater public participation in policymaking, transforming the traditional top-down approach into a more bottom-up, participatory process and citizens can now easily access information about government policies and programmes and engage in public debates on various issues; this power shift has meant that decision-making is now more democratic and transparent. Information and communication technology (ICT) has also made the policymaking process much easier for governments to collect, store, and analyze vast amounts of data, often in real-time; which this data can be used to inform policy decisions and evaluate the effectiveness of existing policies; for instance, in the healthcare sector, data analytics tools can help identify emerging public health threats, improve patient care, and reduce costs or in education, data can be used to monitor student performance, improve learning outcomes, and optimize resource allocation (Bertot et al., 2010). Therefore, using ICT in policymaking has tremendous potential to improve the quality and efficiency of this public activity.

ICT has become an essential tool for modern governance, easing effective policymaking and enhancing collaboration among various stakeholders. According to Hazarika (2017), ICT supplies the necessary infrastructure and tools for managing information, adjusting to changing social contexts, and implementing policies; decentralized policymaking, and direct stakeholder involvement, are now possible thanks to these advancements. E-government systems and AI tools contribute significantly to public participation and

liability in policymaking (Frantzeskaki and De Haan, 2009, quoted by Singh and Kour, 2020). Governments can collect public opinions and feedback, forecast policy outcomes, and explore different possibilities using predictive analytics, simulation modelling, and optimization methods; ICT can reshape administrative processes, streamline resource distribution, and improve access to government services (Wyatt et al., 2013).

In conclusion, the role of ICT in policymaking is multi-faceted and transformative. It can democratize the policymaking process, enhance transparency, and improve service delivery. This profound transformation also shifts users to new challenges and opportunities. As we progress into an era where ICT dominates every aspect of our lives, critically examining its implications for policymaking is crucial. How can we mitigate the risks while maximizing the benefits? How can we ensure that this digital revolution leads to inclusive development? These are the questions that will be addressed in the following section.

2.2.1. Challenges and opportunities of ICT in policymaking

The rise of ICT-enabled innovations, their influence on public interaction with government, and how different digital platforms play crucial roles in this process. Challenges such as the "digital divide" may result in exclusion from development outcomes and infringe on total access to the policymaking process; ICT has transformed policymaking towards a more open, efficient, and effective model while strengthening democracy by providing alternative results and feedback" developing policies surrounding ICT-enabled strategies create global development and constant experimentation will better prepare policymakers to thrive in the future (Chourabi, 2012). The merging of ICT-enabled innovations, such as user-driven applications based on social computing and mobile technologies, is changing how people use the Internet to communicate and interact (Misuraca et al., 2011). Most European citizens embrace the "collaborative Internet"; they expect to be able to interact with city governments using ICT platforms as they enable individuals, businesses, and governments to perform a wide range of activities effectively; these platforms can be categorized into three main groups: content, transactional, and collaboration (Theyti et al., 2013).

Content platforms refer to digital platforms that allow users to access, create, and distribute digital content, such as music, videos, and written content (e.g., YouTube, Spotify, and WordPress). Transactional platforms facilitate transactions between buyers and sellers, enabling individuals and organizations to buy and sell goods and services, transfer funds, and conduct online banking (e.g., eBay, Amazon). Collaboration platforms enable individuals and groups to work together to achieve common goals,

helping communication, information sharing, and collaboration among individuals, teams, and organizations (e.g., Slack, Trello, and Microsoft Teams). As the discussion goes through the transformative implications of ICT in policymaking, it becomes clear that the intersection of these digital platforms with public policy carries both profound challenges and remarkable opportunities; constant adaptation and policy experimentation are required to harness the potential of ICT for global development fully and to prepare policymakers for a future dominated by digital interactions. Various methods and tools, such as deliberation, voting, and modelling, can support policymaking (Rowe and Frewer, 2005).

Deliberation support includes processes and tools that aid individuals and groups in engaging in meaningful dialogue and discussions to enhance their understanding of complex issues and explore workable solutions. Deliberation support tools aim to foster "quality deliberation" by supplying opportunities for participants to engage in respectful, inclusive, and informed dialogue (Hansson and Ekenberg, 2016). Examples of deliberation support tools include citizen juries, deliberative polling, and consensus conferences. Voting is considered an essential tool in policymaking in societies, as it allows individuals to express their preferences and elect their representatives or policies through elections (Lijphart, 1999). Voting plays a critical role in ensuring legitimacy, as it enables citizens to have a say in the governance of their societies, which can take many forms, including direct democracy, representative democracy, and referendums (Hug, 2019).

Modelling is another tool that can be used in policymaking involving data and analytical tools to create simulations and scenarios that assist policymakers in comprehending the possible outcomes of various policy alternatives (Süsser et al., 2021). Modelling can provide policymakers with insights into the complex and interconnected systems that underpin many policy issues, with examples of modelling tools, including what specific challenges does the "digital divide" pose regarding access to the policymaking process? How can policymakers effectively harness the potential of ICT for global development? What are some specific examples of policymaking tools that incorporate ICT? System dynamics, agent-based, and optimization modelling.

These tools can help the involvement of stakeholders, leading to greater transparency and accountability in policymaking (Renn, 2015). In conclusion, the interplay of ICT and policymaking presents a fascinating landscape teeming with remarkable opportunities and significant challenges. It has become evident that digital platforms can profoundly transform how citizens interact with their governments and engage in policy discourse. However, as promising as they are, these interactions face formidable obstacles, such as the digital divide, which can potentially exclude segments of society from these

transformative developments. However, through constant adaptation and policy experimentation, the full potential of ICT can be harnessed, paving the way for a future dominated by digital interactions. The power of ICT lies in its capacity to democratize policymaking, facilitating deeper involvement from stakeholders and citizens alike and thereby creating a more accountable policy environment.

2.2.2. The promise of ICT in policy Making

The promises of ICT, drawing upon the insights of literature, unfold, highlighting its crucial component. Furthermore, the discussion will shed light on how ICT fosters democratic and transparent policy environments, enhancing public involvement and cross-sectoral collaboration, in a world marked by rapid changes, the promise of ICT lies in openness, cognition, connectivity, and rapidly advancing technologies (Visvizi et al., 2017). Openness eases scalability and innovation, while cognitive computing and artificial intelligence enable personalized policymaking based on rich data. Connectivity, through the Internet of Things, fosters community building and understanding. Rapidly advancing technologies like Virtual reality and robotics challenge the traditional way.

The promise of ICT in policy making is rooted in its capacity to enhance decision-making processes through data-driven insights, increased public participation, and cross-sectoral collaboration (Bertot et al., 2010). By using artificial intelligence, big data analytics, and advanced communication technologies, Policymakers can create strategies based on facts that suit different situations and groups of people (Craglia et al., 2020). Furthermore, ICT fosters a more democratic and transparent policy environment by enabling greater public involvement and helping cooperation among various stakeholders (OECD, 2005).

In a rapidly changing world, integrating ICT in policy making ensures that decisions stay agile and responsive to appearing challenges, ultimately contributing to more effective and sustainable solutions for pressing societal issues (Dunleavy et al., 2006). In conclusion, the transformative potential of ICT in policy making is undeniable. With its ability to enhance decision-making through data-driven insights and foster public participation, is ICT a game-changer?

However, as we move forward, the focus shifts to the emergence of recent technologies and their potential to revolutionize policymaking further. The following chapter will delve deeper into these advancements, unraveling the profound implications they hold for the future of policy making.

Chapter 3. The emergence of new Technologies with a focus on Digital twin

With the transition to this new era, it becomes imperative to continually reassess strategies and adapt to these technological innovations to ensure effective solutions for our societal issues.

Picture 5. A perspective of “The promise of ICT in policy Making “. Source: drawn by the author.



Chapter 3. The emergence of new Technologies with a focus on Digital twin.

This chapter investigates the advent of recent technologies, mainly focusing on the concept of the Digital Twin and its impact on policy making. Section 3.1 begins the discourse by examining the recent technologies in policy making; this section maps out the integration of these technologies into the policy-making process, offering an understanding of how innovative tools and techniques are beginning to reshape this area. Then, it lays the groundwork for Section 3.2, which concentrates on the specific role of Digital Twin in policy making. Section 3.2 conducts a detailed analysis of the application and influence of Digital Twin technology in policy making; this section further provides an in-depth exploration of the functionality of Digital Twin across diverse policy domains, underlining the technology's potential in various aspects of policymaking and the other hand, navigates through the challenges and opportunities presented by the incorporation of Digital Twin in policy making.

3.1. The role of digital twin in policy making

Digital twin technology is becoming increasingly important in policymaking, particularly in urban planning and the rising importance of digital twin technology in policymaking is due to its unique capabilities and implications for urban planning; Digital Twin involve constructing digital models of a city's terrain, buildings, and infrastructure, as well as simulating parameters like jobs, deliveries, traffic, and pollution which this technology provides urban planners with a deep look at their city's inner workings and an idea of how a change might play out and the simulation software that comes with digital twin technology lets urban planners tailor their designs and strategies before making any permanent actions. Often, what seems like a great idea doesn't come to fruition. (Solomon, 2021)

Picture 6. an abstract of "The emergence of Digital twin showing how the cities will change." Source: drawn by the author.



Digital Twin technology is computer models that represent real cities; it use current data to show how people, technology, and infrastructure interact, providing a comprehensive

overview of city changes which these models assist in real-time decision-making by representing the virtual city, adapting as the actual city changes, and enabling predictions and planning across various urban systems (Mohammadi and Taylor, 2021) . Lehtola (2022) further explains that Digital Twin (DT) aid in planning activities by checking necessities and fostering stakeholder inclusion; this ensures everyone is updated with the latest and uniform information, making DTs particularly beneficial for cities. Tian (2020) supplies a more specific application of digital twin technology, saying that Digital Twin are complex systems that can simulate real-world scenarios to predict future outcomes; this allows for the identification of potential problems before they occur and the implementation of initiative-taking policies to prevent them; for instance, Digital Twin technology can simulate climate change's effects on infrastructure, identifying potential vulnerabilities and enabling proactive maintenance and repair programs. Finally, Sheikh (2020) highlights that Digital Twin technology can collect and analyze enormous amounts of data from various sources, such as sensors and cameras; this data can be used to create predictive models that aid policymakers in making informed decisions.

Luo (2022) states that Digital Twin technology's potential in policymaking also lies in its ability to ease collaboration between policymakers, stakeholders, and experts, and the 3D model can visualize spatiotemporal information, allowing for the pre-simulation of urban planning initiatives to identify their strengths and weaknesses; this opens up opportunities is to sense urban spaces in digital models, potentially encouraging public participation in the urban planning process in both virtuality and reality, but what unique functionalities do Digital Twin supply to emphasize such a vision of their potential except that can build the virtual model of the city? Pullen (2021) further explains this point by describing Digital Twin as "highly collaborative tools" used to bring together diverse groups to discuss and analyze complex problems, but what sets digital twin apart from existing technologies that would make this promise real? To answer these questions, we first need to understand which technologies Digital Twin are up against and what Digital Twin can offer that other technologies cannot. Starting from the beginning, what approaches and tools have been used in policymaking?

3.1.1. A comparative analysis of Hi-tech tools with Digital Twin: promises and challenges in urban planning.

Traditional data analytics has been used in policymaking for decades, including statistical analysis of observational data, experiments, and microsimulation models; the use of statistical analysis of observational data in the social sciences can be traced back to least the 1950s, and the application of experiments dates even further back; in the 1970s,

microsimulation models, though not as prevalent, began to impact data-driven policy analysis significantly; for approximately four decades, these three elements: experiments, observational statistical analysis, and microsimulation formed the base of policy's quantitative analysis, extending beyond simple descriptive statistics (Giest, 2017). However this approach has weaknesses such as the inability to manage large amounts of data, the lack of real-time data, and the failure to handle unstructured data; additionally, traditional data analytics may need to provide insights on the overall impacts of policies implemented and their strengths and weaknesses; to address deficiencies, big data analytics has been explored as a new approach to policymaking due to the availability of large amounts of data, including real-time data, and the growing capacity we have to manage unstructured data (Shah et al., 2021).

Another technology that was introduced many years ago, which can provide 3D models of a structure, is Computer-Aided Design (CAD). According to Heikkinen et al. (2018), CAD models are primarily used for designing physical objects, such as components of a car or an entire building; while they provide a detailed visual representation, they are static models; for instance, an architect might use a CAD model to design a building, but the model cannot show how the facility will react to different weather conditions or usage patterns over time or providing insights into potential structural issues or maintenance needs before they occur—moving forward to other technologies known as Geographic Information Systems (GIS); Robinson et al. (2007) state that , GIS is used for capturing and analyzing spatial data; for example, a city planner uses GIS to map out the city's infrastructure, such as roads, buildings, and utilities, while GIS can provide a detailed spatial analysis, noting that the data it is not typically linked to real-time data, a difference that digital twin of the city has marketed is providing real-time data for example on traffic, and allowing for dynamic planning and management.

Another technology is Building Information Modeling (BIM); Xie et al. (2022) argues, BIM is a technology that can support policymaking by providing a digital representation of a building or infrastructure project that can be used for design, construction, and maintenance; however, BIM has its weaknesses, such as the lack of standardized policy, which can be a barrier to implementation. The more recently updated technologies that have emerged are known as Internet of Things (IoT) Platforms; Babun et al. (2021) argues , Internet of Things (IoT) platforms can provide real-time data and analysis that can inform decision-making, IoT platforms enable the collection and integration of data from various IoT devices, which may be embedded in anything from household appliances to industrial machinery; While these platforms can provide valuable real-time data . The author further explain they primarily focus on data collection and do not provide the

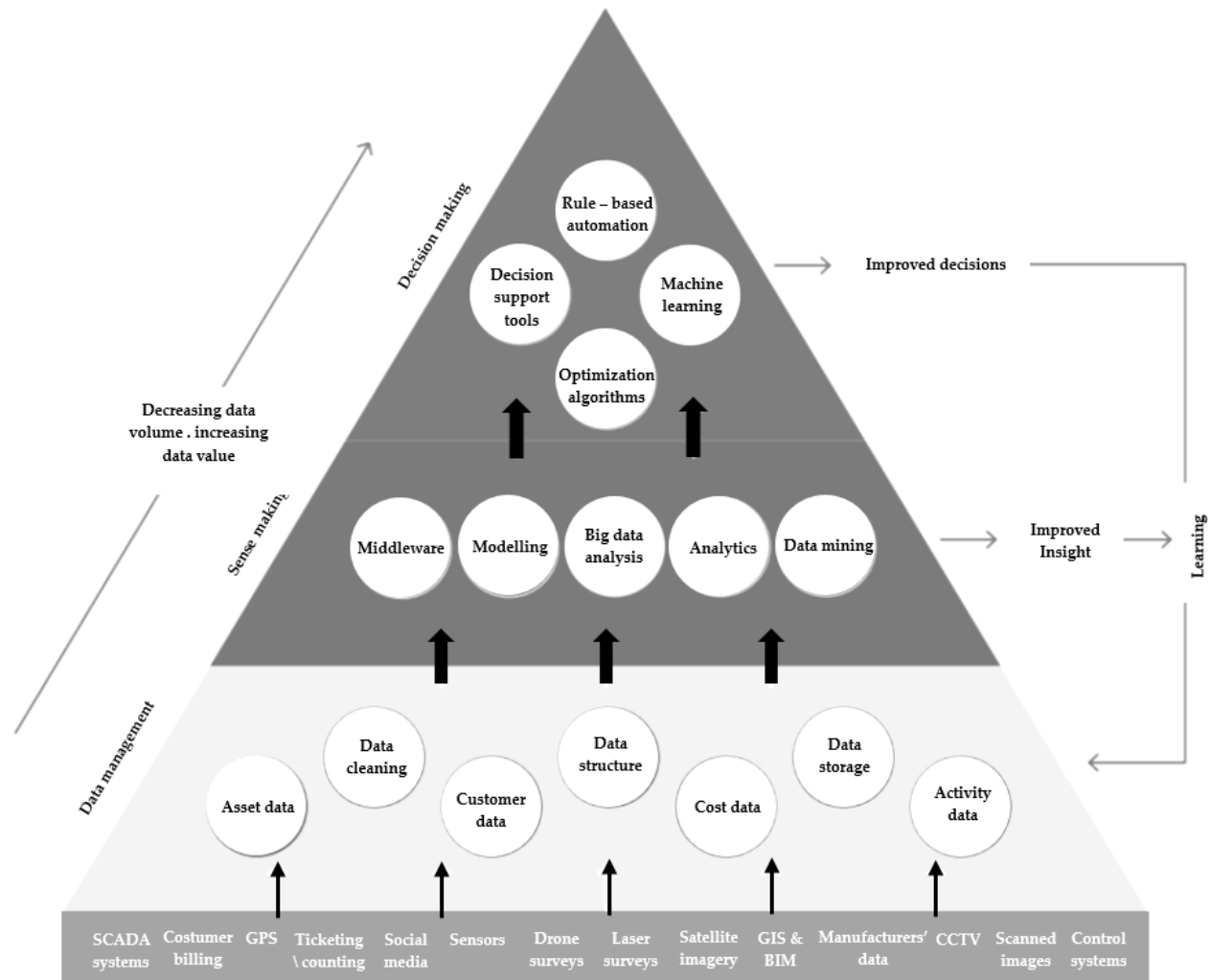
comprehensive modelling and predictive capabilities like digital twin that have been advertised; for instance, an IoT platform might inform you that a machine is overheating, but a digital twin could predict this issue before it happens based on numerous factors like usage patterns and external conditions.

Despite discussing what other technologies cannot offer, according to Wan et al. (2019), Digital Twin technology poses a question on how to make it more beneficial or the concept of Digital Twin is only a marketing catchphrase? People often think a Digital Twin, a virtual model of a city, is just about looking exactly like the actual city (there is a premise that most marketers have claimed that every problem can be solved; when one does not need to implement an idea in reality after investing a lot of money and time to see if the outcomes are positive or negative); conversely, that is unnecessary; detailed 3D models are helpful; but, models that use mathematics to show how the city works are more valuable than just the models representing the city's overall pictures.

According to Wan et al. (2019), for a city a Digital Twin needs to be practical; data inputs and details should be customized according to the purpose and adaptable to changing goals and technological advancements; this suggests Digital Twin does not always need real-time data or the finest spatial unit of analysis. Instead, the outcome should match the scale of the policy request; for broader issues, a connected network of digital twin models might be more beneficial than a singular one. A digital twin technology can be practical when it has been paired with a new governance framework that offers valuable insights; this creates a "digital twin strategy," a purposeful interaction between technology and governance that addresses specific local policy needs and aims to achieve desired policy outcomes; a digital twin can be understood as a virtual model of a tangible object or system (Wildfire , 2018).

The UK's National Infrastructure Commission (NIC) highlighted in their 2017 report titled "Data for Public Good" the immense possibilities that data and digital technology can enhance decision-making processes. They recommended the creation of a national digital twin, envisioned as a national asset aimed at strengthening the efficiency, service quality, and value generated by the support, processes, and systems. A similar earlier version of the diagram has been presented in an industry paper by Mott MacDonald (Wildfire, 2018).

Figure 6. Data Transformation: Unleashing the Information Value Chain for Enhanced Outcomes (Centre for Digital Built Britain, 2018). Source: concept framework (Wildfire, 2018)



According to Chakraborty and McMillan (2017), what is necessary is an information-rich city provided with intelligent models enabling the planning and design of city elements; therefore, new tools are needed to plan and build infrastructure while involving the community. Several tools and methodologies to achieve community participation have been tested, all of which serve the fundamental principle that cities are made for the community. Thus, communities should have a say in planning (Davis et al., 2013). According to Thoneick (2021), recent studies focus mainly on two aspects: either communicative methods as a way to increase the quality of participation or digital participation procedure facilitated by technological development; digital participation

methods have been used in participatory processes for the past 15 years; some of these technologies include volunteered geographic information (geographic information systems (GIS), virtual reality technologies, computer vision, and social media tools (Slaev et al., 2019). Digital Twin could integrate these technologies to create a story and robust system for community participation during the planning stage of infrastructure projects; a digital twin enables changes and representation (e.g., future designs) and minimizes risks and associated costs in the real-world through collaborative planning and participation (Shahat et al., 2021). However, the complexity of the city and the interdependencies between its elements (humans, infrastructure, and technologies) have made it a challenge to integrate the details and develop a platform enabling community engagement (Clinical and Translational Science Awards Consortium et al., 2011).

Another difficulty that should be pointed out is the cost of implementing and maintaining Digital Twin systems, and the significant investments required in terms of hardware, software, and training can be prohibitive, especially for smaller organizations or governments with limited budgets; another limiting factor is technology's reliance on data which is not evidence-based (Hofer, 2019). As Agrawal (2021) warns, if the underlying data used to create Digital Twin is incomplete or inaccurate, the predictive models generated may be flawed; If we cannot correspond our knowledge of cities to the digital twin, we will not be able to design, evaluate, or even regulate the Digital Twin using preventative measures. Of course, this argument does not mainly discuss data or AI ethics; we should not also be too optimistic that digital twins can quickly fix city and infrastructure issues independently. However, the question is how quickly people and policymakers can adapt to these technologies and maximize their use, how long they can last to be used, and whether or not the Digital Twin is a game-changer.

A dynamic new team called the Digital Framework Task Group (DFTG) was formed in response to the NIC report's suggestions. Placed in the heart of Cambridge, they are a part of the forward-thinking Centre for Digital Built Britain (CDDB); their mission is to progress the successful development and adoption of a digital framework focused on infrastructure data and the revolutionary concept of digital twins.

Figure 7. The Gemini Principles for developing digital twins of the built environment (Source: Centre for Digital Built Britain, 2018)

<p>Purpose: Must have a clear goal.</p>	<p>Public good Must be used to deliver genuine public benefit in perpetuity.</p>	<p>Value creation Must enable value creation and performance improvement.</p>	<p>Insight Must provide determinable insight into the built environment.</p>
<p>Trust: Must be trustworthy.</p>	<p>Security Must enable security and be secure itself.</p>	<p>Openness Must be as open as possible.</p>	<p>Quality Must be built on data of an appropriate quality.</p>
<p>Function: Must Function effectively.</p>	<p>Federation Must be based on a standard connected environment.</p>	<p>Curation Must have clear ownership, governance, and regulation.</p>	<p>Evolution Must be able to adapt as technology and society evolve.</p>

They have already made steps by releasing the "Gemini Principles" in 2018 - a guidebook for the national Digital Twin project; the first principle, properly named 'Purpose', emphasizes the key relationship between the Digital Twin technology and the policy results in it is designed to support; it is a tool, not the end game, created to help us make smarter, more informed decisions, it responds to the 'one-size-fits-all' approach of early smart city efforts, encouraging us to consider the unique social and political traces of each problem we tackle. This principle validates the need for a Digital Twin. It gives us a blueprint for how to build and operate it effectively. The second principle is 'Trust', an intense topic given recent incidents of data misuse and privacy scandal. It serves as a reminder that building a dependable Digital Twin requires a delicate balance - we need openness, transparency, and stringent security. It is a challenge that needs a dual approach, intertwining governance through technology. Finally, the 'Function' principle. It underscores that the digital twin, a unified model system, must work efficiently in pursuit of its purpose. It must also be ready to evolve with the ever-changing landscape of technology and society. Throughout the Gemini principle it states that it is a futuristic vision, but these principles show us it is a future we are ready for."

The speed at which policymakers can adapt to new technologies and maximize their use depends on various factors, such as the complexity of the technology, the availability of resources, and the level of expertise of policymakers and stakeholders, the more complex the technology, the longer it may take for people or policymakers to adapt and make the most use out of it (Davis et al., 2022). In conclusion, Digital Twin technology has significant potential to enhance policymaking. However, what differentiates Digital Twin from other technologies is the ability to predict, which no other technologies have. However, merging other technologies such as the Internet of Things (IoT), Artificial intelligence, big data, and other exciting ones that have been said into the Digital Twin technologies could make it possible to reinforce participation and get more reliable resources through the technology in policy making. The unique functions that digital twins offer include real-time data integration, dynamic adaptability (since most people have already used technological tools in their daily life), comprehensive modelling, predictive capabilities, and primary levels of collaboration. These features collectively support a vision of digital twins as a powerful tool in policymaking, capable of simulating real-world scenarios, showing potential problems before they occur, and implementing initiative-taking policies. However, it is essential to note that Digital Twin technology is not a panacea. As we venture into the next chapter, we delve into real-world applications of these technologies through various case studies. These instances will supply a more tangible understanding of the concepts discussed so far, illustrating how Digital Twin technology has been used in actual policymaking scenarios to know whether Digital Twin is a fake marketing slogan.

3.2. The growing availability of data.

Historically, policymakers have relied on expert opinion, political judgment, and intuition. The world we live in now is dominated by technology; however, technological advancements have transformed how government policy is developed, implemented, and evaluated. (Janssen and Wimmer, 2015) In policymaking, recent technologies have played a significant role in policymakers' decisions, from collecting data, analyzing it, and presenting it to the public; a considerable advantage of using recent technologies in policymaking is getting information based on data.

In the words of Concilio and Pucci (2021), "We are seeing a rise in the creation and accessibility of vast amounts of data; different political groups are utilizing this data, and it is providing new opportunities for decision-making in both public and private sectors, Simultaneously, there is a rapid growth in technology that helps in creating, managing, and analyzing this data, a phenomenon referred to as 'data shake'; which is not just about

Chapter 3. The emergence of new Technologies with a focus on Digital twin

more data becoming available, but also about quick access to data-related technology which as a result, we are seeing data-driven methods being used across many policy areas, from health and transport to immigration and environmental policy, and even in fields like social sciences; this is large since not only is there more data available, but the technology to manage and analyze this data has also become easier to use.

Picture 7. a conceptual view of the "growing availability of data ". Source: drawn by the author.



One of the key benefits of new technologies is that it can provide policymakers with a more extensive pool of information; with technology, policymakers can gather all the necessary data needed to make informed decisions, and data comes from different sources, such as online surveys, and smartphone apps that track a person's daily activities (Brand-Miller and Gallo, 2016). The United Kingdom (UK) government launched their Covid-19 contact tracing app that allows them to track citizens' movements and their exposure to the virus; the data collected can be analyzed and provide a precise picture of the situation, making it easier for policymakers to make decisions; the use of data has allowed policymakers to make more evidence-based decisions (Samuel and Sims, 2021).

Recent technologies can enhance public participation and engagement in policy processes (Pagliari and Aziz Sheikh, 2018). By leveraging technology, policymakers can create avenues for citizens to contribute to developing more effective policies. For instance, as Patel et al. (2021) put it, online platforms can provide citizens with easy access to government services, reducing the time and resources needed to operate bureaucracies and, on the other hand utilizing artificial intelligence and machine learning systems by governments had created an opportunity to automate procedures such as data entry and management, in that way which reduces errors and operational costs; for instance to gathering data, policymakers use social media to engage with the public, Social media platforms such as Twitter and Facebook allow policymakers to communicate with their constituents, dispel misinformation, and collect feedback on policy decisions. According to National Archives and Records Administration (2017), the White House launched a social media initiative with Twitter known as 'Did You Know'; it aimed to educate people on the policies they were proposing and encourage them to give feedback; this, in turn, helped policymakers to know the public's concerns and tailor their policies to suit the public's needs better. Despite the advantages of the new technologies in policymaking, some problems arise; despite the amount of data available to policymakers, they still face difficulties in interpreting the data and presenting it in a way that's understandable to the public. In a study by Lusk and Norwood (2011), they concluded that in understanding data due to the complex nature of analysis affects policy decisions as data may be misinterpreted, leading to incorrect policies being implemented with just reliance on technology that policymakers may overlook other sources of information; policymakers may face the risk of tunnel vision, which may lead them to ignore other sources of information, such as feedback from the public.

Although recent technologies offer several benefits, other significant challenges are associated with their incorporation into policymaking. Addressing the 'technology gap'

is crucial to preventing the marginalization of low-income and older households (Chen et al., 2014). Data accuracy, reliability, and privacy concerns can surface as data collection, storage, and sharing become more integral to policymaking (Jotischky, 2017). Furthermore, using technology in policymaking may cause ethical concerns such as privacy violations; "privacy "is a paramount issue as policymakers collect data and require careful handling. In 2018, the Facebook data scandal revealed how personal data could be misused, leading to ethical concerns; that privileged information as citizens' rights can be violated. One such challenge is the issue of inequality; recent technologies like social media platforms and algorithms can unintentionally increase existing inequalities by giving more prominence to some voices who have greater access while pushing others who are considered misers to the sidelines; furthermore, access to technology and digital learning is not guaranteed for all citizens, which could exclude some individuals from taking part in policy processes (Lindsay , 2018) .

Another challenge related to new technologies in policymaking is the potential for their misuse; as noted by Baker and Schuman Baker (2015), the rapid and complex growth of technology makes it hard for policymakers to keep up and create needed protections for people's rights and privacy; when technology advances faster than laws, there is a risk that these tools could harm human rights, reduce privacy, and influence public opinion. Moreover, the operation of new technologies in policymaking can pave the way for innovative policy solutions; according to Manning and Parry (2007), these tools can strengthen the ability of policymakers to devise policies that are forward-thinking, ambitious, and agile; an example of this is the rising concept of smart cities, which are technology-driven, environmentally innovative, and aimed at enhancing citizens' quality of life (Wong et al., 2019). In conclusion, recent technologies can significantly influence policymaking processes. They offer many benefits, ranging from increased citizen participation and transparency to acceleration of policymaking processes and help to devise more sustainable and innovative policies by using the growing volumes of data. However, there are also concerns about technology and how it can affect society and the individuals living in it, being conscious of the adverse impact of relying on technology and ensuring that they engage with the public to obtain a balanced view.

Chapter 4. Case studies

Chapter 4 delves into the case studies from Europe. Section 4.1 explores the instances of Hervanta in Tampere and the Kalasatama district in Helsinki. It provides an exhaustive understanding of how these digital twins contribute to efficient urban management and decision making. Shifting focus to Switzerland, section 4.3 offers an in-depth examination of the city of Zurich's digital twin, illustrating the complexities of representing an entire city in a virtual environment and its transformative implications for urban planning. Section 4.2 then moves to the Docklands area in Dublin, a case study that underscores digital twins' multifaceted benefits and challenges in urban development.

4.1. Methodological framework of case studies

As urban planners, it is our responsibility to understand the ways in which technological advancements can strengthen societal participation and improve communication in our swiftly progressing digital age.

It is arguable to discover whether the use of Digital Twin technology in urban planning is truly transformative or merely a promotional catchphrase.

For this purpose, the cities of Helsinki, Zürich, and Dublin have been selected as main points due to their pioneering adoption of Digital Twin technology and their rich culture of public participation. Historically, these cities have demonstrated unwavering dedication to developing civic involvement through platforms such as referendums, public hearings, and other participatory movements. The use of Digital Twin technology in these cities encourages this tradition, with its dual application as a digital platform for citizen engagement and as a medium to uplift the quality of public participation. Consider, for example, how these cities have intertwined technology with community participation - Helsinki's democratic ethos that fuels technology-supported public decision-making, Zürich's utilization of digital platforms for effective citizen engagement, and Dublin's endeavor to employ technology for heightened communicative efficacy. These cities stand as distinct yet coherent demonstrations of the intertwined potential of technology and societal participation.

The Gemini Principles and the Information Value Chain (IVC) were chosen as the guiding frameworks for this analysis due to their direct relevance and applicability to Digital Twin technology in the context of urban planning. The Gemini Principles and the Information Value Chain (IVC), developed by the Centre for Digital Built Britain, provide a guiding philosophical perspective for the deployment of Digital Twins, emphasizing three key components: Purpose, Trust, and Function. They highlight the importance of a well-defined purpose for the Digital Twin that aligns with public good; the necessity of trust in the data quality, security, and privacy; and the need for the Digital Twin to be functional, secure, and reliable. These principles align directly with the main aspects to be evaluated when considering the successful implementation of Digital Twin technology, making them an ideal choice for this analysis. On the other hand, the IVC offers a structured approach to understand how raw data is transformed into valuable insights - a fundamental process in the operation of digital twins. It provides a clear path, showcasing how data is collected, processed, stored, and analyzed to create information that is then used to support decision-making processes. In the context of digital twins,

this framework is particularly relevant as it highlights the steps through which urban data is turned into actionable knowledge, leading to more informed, effective urban planning decisions. In essence, both the Gemini Principles and IVC provide structured, specific, and insightful frameworks to examine the involved process of implementing and operating digital twins in urban planning. They enable the evaluation of Digital Twin projects not just on their technical implementation, but also on their societal impact, data quality, and overall efficacy in enhancing urban planning and citizen engagement.

In Helsinki's case, Digital Twin technology is not simply an advanced tool integrated into the city's operations. Instead, it has been argued that it has also been adopted as a toolbox through which to encourage, facilitate, and strengthen citizen participation in urban development plans. Through visualizations of proposed urban projects by combining the Digital Twin and Virtual reality (VR), this combination of technologies provides residents with an opportunity to comprehend and appreciate the potential impact of planned developments in their city. By making these visualizations accessible and user friendly as per se', the city of Helsinki is fostering informed discussions among its residents and encouraging public input into the decision-making processes. Thus, the Digital Twin technology in Helsinki is employed to serve a definite, agreed-upon purpose, and is an example of the 'Purposeful' aspect of the Gemini Principles.

However, the implementation of such technology is not without challenges. As data becomes an increasingly valuable asset, concerns regarding privacy and security have grown in cycle. Helsinki's authorities have had to grapple with striking the right balance between maintaining transparency in their use of Digital Twin technology and ensuring that residents' data privacy is upheld. This dilemma underscores the difficulty of implementing such advanced technology in a responsible, ethical manner. It emphasizes the need for the creation and enforcement of robust data protection and privacy policies to maintain trust in the technology and its use by public authorities. Furthermore, it highlights the need for digital literacy programs to ensure that residents fully understand the implications of the technology and the ways in which their data is used.

By fostering a city-wide understanding of technology, Helsinki can ensure that its residents are equipped to make informed decisions about their data and its usage. Overall, Helsinki's deployment of Digital Twin technology shows the potential of digital tools in advancing democratic participation. Despite the complexities inherent in maintaining data privacy and transparency, the city's successful implementation

underscores that the key to navigating these challenges lies in a careful, balanced approach guided by the Gemini Principles.

Zürich's application of Digital Twin technology is principally shaped by the 'Value Creation' aspect of the Gemini Principles, demonstrating an innovative approach to civic engagement. The city leverages digital platforms to transform a wealth of raw data into useful information, which is then disseminated among its residents, thereby enriching their understanding and involvement in the urban development process through the online platforms and public application which each citizen can contribute to the decision making process by expressing their idea and critics. This strategy presents a cutting-edge method of promoting active participation and fostering an informed citizenship, thereby enhancing the overall democratic process. However, the effectiveness of this strategy is inherently dependent on two crucial elements: data quality and citizens' digital literacy. Data quality is paramount in this context as the conversion of raw data into meaningful information requires reliable, accurate and timely data. Poor quality data can lead to inaccurate information, misleading representations, and ultimately, flawed decisions. Hence, Zürich's administration must consistently strive to improve data collection, verification, and processing mechanisms to ensure the reliability of the digital twin.

Secondly, the effectiveness of this technology as a tool for civic engagement is contingent upon the digital literacy levels of the citizens. Without an adequate level of digital literacy, citizens might find it challenging to interact with the digital platforms, understand the information presented, or effectively engage in the participatory processes enabled by the digital twin. It indicates that the city needs to invest in continuous digital literacy programs, ensuring that all residents, irrespective of their age, socioeconomic background, or education level, can effectively utilize the digital platforms and participate in the urban development process. Thus, while Zürich's application of Digital Twin technology exemplifies an innovative approach to amplifying civic participation, it also underscores the ongoing need for attention to data quality and digital literacy. As such, the success of Zürich's Digital Twin initiative hinges on the city's ability to continuously improve these areas and adapt to the evolving digital landscape.

Dublin's utilization of Digital Twin technology presents a compelling example of leveraging digital tools to amplify communicative efficacy, in alignment with the 'Openness' principle laid down in the Gemini Principles. This approach involves making data widely available and easily accessible to all citizens, thereby fostering an environment of transparency and trust. By openly sharing data and information, Dublin's

administration allows its citizens to be part of the city's development and decision-making processes. This openness, in turn, strengthens the public's confidence in the city's governance and furthers democratic participation. However, the adoption of this open approach is not without its challenges. The city is tasked with managing and updating an enormous volume of data regularly, which demands substantial technological and human resources. Ensuring the data is accurate, up-to-date, and easily accessible presents a complex task, requiring robust data management strategies and infrastructures. This is where the necessity of a well-devised and efficiently executed data management strategy becomes evident. The city needs to invest in data infrastructure and digital skills, apply advanced data management techniques, and maintain a vigilant approach to data quality control to successfully uphold this principle of openness.

The analysis of Dublin's implementation of Digital Twin technology is pointed by Gemini principle which provides a robust framework for assessing the deployment of Digital Twins, emphasizing aspects such as public good, value creation, and trustworthiness. By applying this framework, we can gain a deeper understanding of the successes achieved and the challenges encountered during the implementation of Digital Twin technology. In the case of Dublin, these principles help us appreciate how Digital Twin technology can be harnessed to enhance communicative effectiveness while concurrently underscoring the importance of a comprehensive data management strategy to successfully maintain an open approach. Overall, the Dublin case provides crucial insights into the potential and challenges of adopting Digital Twin technology for public engagement and participation, illuminating a path for other cities embarking on a similar journey.

To extend this analysis, the Information Value Chain (IVC) framework is employed to focus on how the Gemini Principles may map onto a city's implementation strategy. The IVC framework illustrates how data is transformed into useful knowledge and in which part of this framework the citizen and expert participation occurred and which section of the framework aligns with the value creation aspect of the Gemini Principles. This dual-pronged approach allows us to understand how these case study cities use their Digital Twin to gather data, convert it into valuable information, and distribute this knowledge among their citizens to foster participation and discourse. In turn, this provides us crucial insights into the potential of Digital Twin technology as a participatory and communicative tool, equipping us with knowledge to navigate the fast-evolving digital landscape. The methodology includes a review of available literature and public resources, including official city websites and associated digital platforms. I focus on two

primary aspects of Digital Twin application in urban planning: A) **digital participation procedures facilitated by technological developments** and B) **communicative methods that enhance the quality of participation**. The analysis then also applies the Gemini Principles to assess the efficacy of Digital Twin implementation. I evaluate each city's Digital Twin strategy according to these principles, constructing comparative tables that present an overview of each city's alignment with the principles, providing a visual aid for the analysis.

To conclude, the examination of Helsinki, Zürich, and Dublin offers invaluable understandings into the nuanced usage of Digital Twin technology in urban planning and citizen participation. These selected case studies provide a compelling display of how technology can strengthen civic participation, thus offering key perceptions into the potential of Digital Twin technology as a tool for participation and communication enhancement. As we delve into each city's adoption of Digital Twin technology, we better understand the potential implications, opportunities, and **challenges this technological advancement presents**. These findings, alongside critical evaluations based on the Gemini Principles and the IVC framework, guide our understanding of the successes and challenges in implementing digital twins in urban planning. The combination of quantitative and qualitative methodologies used in this analysis provides a comprehensive evaluation of Digital Twin technology's role in the urban planning processes of Helsinki, Zurich, and Dublin. The research explores themes of the measurable impact and effectiveness of the technology, trust issues including security and data quality, the requirement for a transparent data environment, and the need for clear data governance regulations. For future research and implementation strategies, I recommend developing a standards-based approach to ensure the effective and sustainable application of Digital Twin technology in urban planning. The research also emphasizes the necessity of continued focus on areas identified as gaps in the study, including assessing the impact of technology, trust issues, and functional effectiveness. By addressing these areas, we can ensure that Digital Twin technology serves its intended purpose of enhancing the quality of life for citizens without compromising on security, quality, or evolutionary capacity. In summary, the selected case studies exemplify the interplay between technology and civic participation, illustrating the capacity of Digital Twin technology to shape our journey towards a technologically advanced urban future.

4.2. The cases of digital twins of Hervanta in the Tampere and Kalasatama district in Helsinki

Picture 8. An abstract of Helsinki city. Source: drawn by the author.



Helsinki is pioneering Digital Twin technology for digital engagement and communication enhancement; initiatives include their open data project, which freely provides a wealth of city data to the public, and Kerrokantasi, an online tool for public participation. These are steps towards creating a comprehensive digital twin of the city, providing rich data for various uses, and fostering a culture of public involvement in city development.

Helsinki City (2018) argues that digital twins represent a powerful tool, capable of streamlining several urban intelligence tasks; they can contribute significantly to policymaking, geared towards increasing efficiency in crucial areas like traffic and power system management; moreover, these digital counterparts can be deployed for tackling issues related to climate adaptation and adjustment of mobility models. According to Hawrot (2021), The role of Digital Twin in enhancing transportation is clear from Charitonidou's work related to the automatic traffic test point in Hervanta, Tampere; this large city-based Digital Twin project started because of the need to look into details linked to a public transport project, and the main aim of the Hervanta Digital Twin was to provide a capable platform for testing ways related to self-driving car studies and the heart of this project is to use the Digital Twins for self-driving car tests and study putting a focus on new ideas, doing more with less, and quick changes; with a strong belief that Digital Twin could significantly cut the costs of old testing ways in self-driving car studies.

Delving into 'Urban development with dynamic digital twins in Helsinki city,' Hamäläinen (2020) investigates the case of the Digital Twin of the Kalasatama district. Her focus revolves around Open Cities Planner, a supplemental application designed within this project's scope to fortify the utilization of the "Kalasatama Digital Twin platform". **The application seeks to familiarize citizens with Digital Twin data usage while fostering participation and interaction among the residents of Kalasatama;** an illustrative example of this application in action is the 'public participation GIS (PPGIS) poll' (The poll employed the application to ascertain places within the district that residents would recommend to visitors). Hamäläinen's assertion that 'Digital Twin platforms were also harnessed to incorporate citizens into urban development initiatives in Helsinki' sparks curiosity about the potential of digital twins in fostering participatory design methods. While Hamäläinen asserts that the Digital Twin of Helsinki has made 'design processes more transparent and open', access to digital twins often remains limited for the general public.

The study adopted an interpretive research approach with a qualitative exploratory research strategy to examine the role of participation in Digital Twin implementation. According to Hamäläinen (2021), Semi-structured interviews were carried out with urban developers from Helsinki and Pietarsaari. The interviewee also represented two organizations: building SMART Finland and xD Visuals Ltd., advocating for building information modelling standards and providing 3D city modelling and Digital Twin solutions, respectively; representatives from companies offering Digital Twin platforms, technical solutions, and consulting services for smart city developers were interviewed as well; Data was supplemented with secondary sources from official project reports, and company websites and marketing materials and analysis followed inductive, content analysis techniques; interviews were conducted and recorded through online platforms, mobile phones, or in person and notes were taken during interviews and transcriptions were made post-interview.

The report below is to give an overall understanding of the case study methodology of Helsinki done by Hamäläinen (2021, p 203- 204).

The indispensability of robust data infrastructure for a smart city forms the basis for various city applications like urban construction and transportation design. This perspective was supported by an interviewee who highlighted the importance of a robust digital city model and data infrastructure for enabling quick and agile urban simulations. The interviewee (as CEO) introduced the concept of Urban Information Modelling (UIM) as a comprehensive view of the city, comprising 3D modelling of the entire city and its

built environment, including Geographical Information System (GIS) data. UIM forms the basis for creating a city-level Digital Twin and allows a holistic observation of the city's life cycle. The Pietarsaari city interviewee considered the possibility of a comprehensive city model that could ease city planners' work and eliminate redundant tasks such as physical site visits. However, interviewees of the "Helsinki city "and "Consultant agency, Helsinki smart city development "felt that current 3D data modelling and Digital Twin technologies are most beneficial when modelling specific city functions or use cases. Examples include using a Digital Twin to analyze city views, wind conditions, microclimates, traffic, and city services, identify and simulate energy leakages in buildings, or aid in building renovation; urban developers could also use a Digital Twin to anticipate the impact of changing climate conditions on the built environment by simulating potential outcomes such as rising sea levels or other weather changes in a specific urban context. The " Consultant agency, Helsinki smart city development " interviewee emphasized the importance of defining the Level of Detail (LOD) for the data model before initiating Digital Twin projects; this LOD helps determine the extent and relevance of data and guides developers in making decisions, thus improving the design of suitable data models and digital twins while has significant potential in urban design, various organizational and technical challenges obstruct its widespread use in innovative city development; for instance, specific city authority processes, such as building permit applications, don't adequately support data generation and sharing in digital formats. Also, some city organizations don't perceive any tangible added value from these new digital technologies for existing business procedures, leading to a lack of technical and human resources investment. The interviewee from the "Building SMART, xD Visual soy "highlighted that the technology aspect of digital twins is functional; however, the real challenge lies in people's readiness to alter their perceptions, attitudes, and actions; for cities to leverage data modelling and Digital Twin technologies more extensively, significant changes in organizational culture and city processes are vital.

Moreover, according to Charitonidou (2022) changes should involve all actors in the urban development value network; having a collective agreement to implement data modeling in urban development projects can aid the adoption and diffusion of data modeling and Digital Twin techniques and this agreement would enable all actors to capitalize on the benefits a dynamic Digital Twin provides; other difficulties to exploiting digital twins in urban planning include handling the volume and size of data files, data integration, and computing power; for example, obtaining the correct data and modifying datasets for 3D models can be challenging, and generating high-quality 3D models can be labor-intensive as the data used may need manual cleaning and preparation; it has

been argued that the Digital Twin project demonstrated the need for substantial computing power due to the integration of large amounts of data from various databases into a visual 3D model and advancements in technology are making it possible to generate realistic digital twins of entire cities, even enabling the processing of large datasets on mobile devices; with the rapid evolution of Digital Twin technology, urban planners increasingly have access to sophisticated tools and solutions, fostering enhanced connectivity between the virtual and physical city.

4.3. The case of the Digital Twin of the city of Zurich

Picture 9. An abstract of Zurich. Source: drawn by the author.



Developing from the work of Schrotter and Hürzeler (2020), the Digital Twin project in Zurich is a pioneering initiative that seeks to create a comprehensive, three-dimensional digital model of the city, improving the city's spatial data infrastructure. Managed by the GIS City of Zurich, the project embodies a significant advancement in cadastral and engineering surveying by integrating the third dimension into digitizing and processing space. The project follows the Federal Act on Geoinformation (GeoIG 2007), a robust governance framework that dictates the definition and management of spatial data, spatial data models, and metadata in Switzerland; it is fully aligned with the INSPIRE Directive and even extends beyond its requirements (Belfadel et al., 2023).

According to Shahat et al. (2021), a core aspect of the project is the innovative application of the Digital Twin concept to spatial data, models, and metadata; according to Jiang (2021), this provides an effective way to manage the life cycle of these elements, by monitoring and updating city components like buildings and roads based on predefined intervals and the initiative has profound implications for cities undergoing rapid changes as it enables real-time linking of physical changes to the digital twin; a significant portion

of the project concerns the construction and real estate industries also it digitally maps construction processes and maintenance activities using 3D spatial data and building models. According to Jiang et al. (2022), Digital replicas depict buildings' operational and structural conditions over time, representing existing, under-construction, and future planned structures. According to Schrotter and Hürzeler (2020), The project is transformative for urban development, as real-world elements are linked to their digital counterparts in real-time, delivering critical insights; it has necessitated an overhaul of the strategy for GIS City of Zurich, which is now a leader in spatial data infrastructure and the utility of the Digital Twin is varied, with applications ranging from environmental modelling and potential energy analysis to urban planning; the project has even employed popular games such as "Minecraft" for participatory processes, allowing the younger generation to contribute to urban planning ideas and overall, the Digital Twin project is has been said revolutionizing the administration of Zurich by improving the city's representation and understanding, and aiding in planning, development, and maintenance of its components. Regarding citizen engagement, Zurich employs technological solutions like mobile apps to enhance the quality of participation, such as the "Züri wie neu" app that enables citizens to report city issues directly. It fosters civic engagement and is set to lead in a new era of urban planning by bridging the gap between digital space and the real world.

4.4. The case of the Digital Twin of Dublin

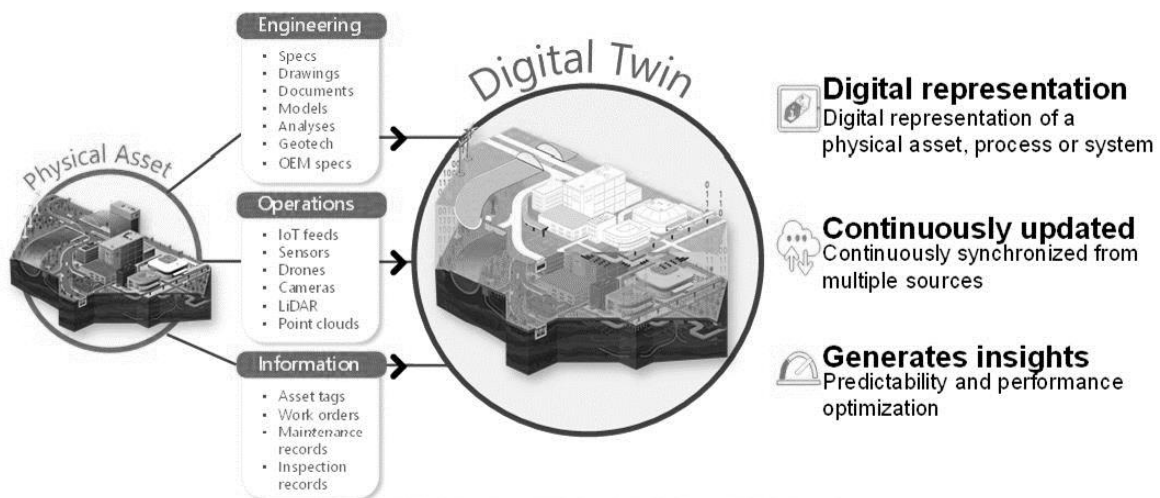
Picture 10. An abstract of Dublin. Source: drawn by the author.



Building upon the research by White and colleagues (2021), it is postulated that Digital Twin technology is a robust tool that can potentially elevate multiple facets of urban intelligence. This technological advancement is highly beneficial in streamlining policymaking, especially in crucial areas such as traffic control, energy system management, and more. Additionally, Digital Twins can be effectively deployed to tackle climate adaptation challenges and modify mobility patterns.

As Gary White et al. (2021) explained, the genesis of this Digital Twin project was an inherent requirement for an in-depth urban planning initiative. The Dublin Docklands Digital Twin project aimed to establish a proficient platform to test urban planning simulations and the analysis of the public reaction to these transformations. At its core, the project harnesses the power of Digital Twins to expedite urban planning while evaluating citizen responses, emphasizing innovation, efficiency, and rapid adaptability. The belief is that Digital Twins can significantly cut costs associated with traditional urban planning methods. The focus of White and his team's exploration is the Digital Twin of the Docklands district in Dublin, with particular emphasis on a publicly accessible 3D city model created as part of this project. The aim is to facilitate citizen participation through Digital Twin data and foster engagement and interaction among the residents.

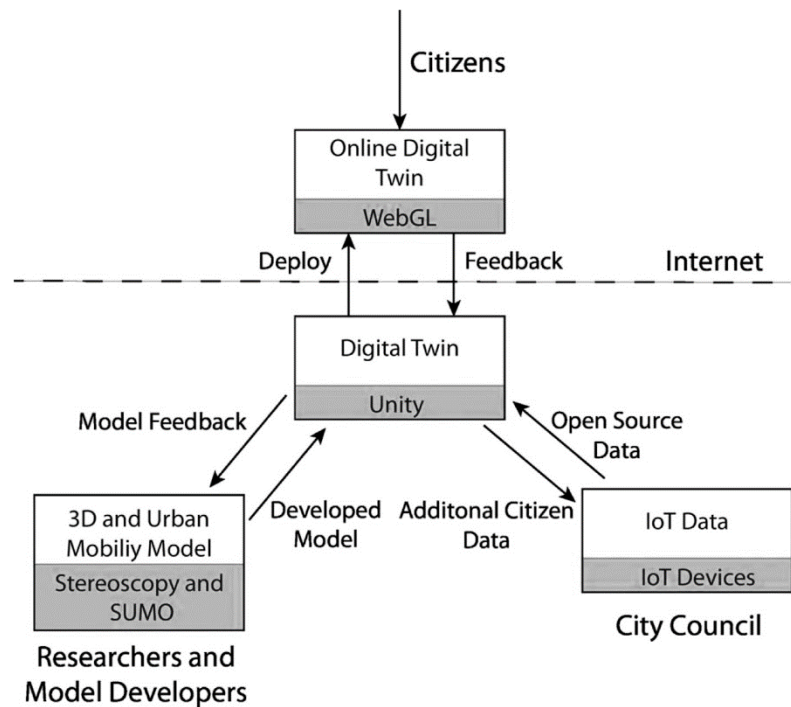
Figure 8. Diagram showing how Digital Twin collects and visualizes data. (Sources: Bentley systems during the ARC industry forum retrieved from Kevin Vivien, 2021)



White et al. posit that 'Digital twin platforms can make policy and urban development initiatives more transparent', initiating dialogue on the potential of digital twins in cultivating participatory methods. Their study utilizes an interpretive research approach with a qualitative exploratory research strategy to analyze the role of citizen participation in Digital Twin implementation. They stress the need for robust data infrastructure as the backbone for a smart city, forming the foundation for various city applications, including urban planning and policy decisions. The authors propose the concept of Digital Twin as

a comprehensive cityscape encompassing a 3D model of the entire city, including IoT data and citizen feedback.

Figure 9. Online Digital Twin interaction diagram. Source: White et al. 2021.



However, despite its immense potential in urban planning, certain organizational and technical obstacles obstruct the widespread adoption of digital twins in city development. For instance, specific city authority procedures, such as public feedback mechanisms, do not effectively support data generation and sharing in digital formats. Also, some city organizations fail to recognize the tangible value addition these emerging digital technologies offer to their existing processes, resulting in insufficient investment in technical and human resources. The authors emphasize that while the technological aspect of digital twins is functional, the real challenge lies in people's readiness to modify their perceptions, behaviors, and actions.

Significant transformations are required in organizational culture and city processes to fully exploit the potential of data modelling and Digital Twin technologies. Furthermore, these changes should encompass all urban development value network stakeholders. Having a consensus to incorporate data modelling in urban development projects can facilitate the adoption and diffusion of data modelling and Digital Twin methodologies, allowing all participants to benefit from the dynamic advantages a Digital Twin can offer.

However, challenges persist in leveraging digital twins in urban planning, including data volume and size management, data integration, and computational power.

The Dublin Docklands project showcases the significant computing power required for Digital Twin technology, integrating large volumes of data from various databases to form a 3D visual model. As technology evolves, creating realistic digital twins of entire cities is becoming increasingly feasible, even allowing the processing of substantial datasets on portable devices like mobiles. This rapid development in Digital Twin technology equips urban designers with sophisticated tools, fostering a more profound connection between virtual and physical urban spaces. The experience from the Dublin Docklands serves as an enlightening example of the transformative potential of digital twins in urban planning and design. Incorporating this technology into city development enables the creation of plans that are more responsive and efficient, benefiting both the city and its residents. Future studies should further explore digital twins' potential in urban planning, specifically how this technology can enhance participatory design and increase citizen engagement in urban development.

Chapter 5. Analysis of the case studies

Chapter 5 provides an in-depth analysis of implementing Digital Twin technology in Helsinki, Zurich, and Dublin, underpinned by the Gemini Principles and information value chain, which function as a guiding compass. Section 5.1 provides an evaluative analysis of the cases, employing the Gemini Principles as a framework for assessing each city's purpose, trust, and function of the Digital Twins. It critically discusses their contribution to the public good, value creation, insight, data security, openness, and quality. The section also highlights the potential challenges and gaps in data collection, access, quality, and frequency. Section 5.2 shifts the lens to focus on Information Value Chain (IVC) to examine transforming data into actionable insights and it scrutinizes each value chain stage - data collection, processing, analysis, decision-making, and outcome evaluation - in light of the corresponding Gemini Principles. The analysis underlined the necessity for more comprehensive data collection strategies, robust data processing safeguards, transparency in data analysis techniques, straightforward evidence of decision-making, and quantifiable outcome measures. Despite the challenges, this chapter leaves the reader with a sense of enthusiasm and anticipation, recognizing that addressing these challenges could enhance the power of Digital Twin technology in urban planning. It concludes by raising the question of readiness to seize this potential and forge a path towards a future where Digital Twins guide informed decisions, especially in our unpredictable world.

5.1. The case study's analysis of Helsinki, Zurich, and Dublin."

In Helsinki, based on literature, the application of Digital Twin technology has been introduced as a form of "digital participation procedure facilitated by technological development." And utilizing the city's digital platforms for citizen feedback and decision-making integration refers to "communicative methods as a way to increase the quality of participation."

- A) **Digital participation procedure facilitated by technological development:** The city launched an open data project, which makes large amounts of city data available to the public, including data on city facilities, transportation, and demographics. This could be viewed as a substance to a digital twin, where data about the city is digitized and made available for various purposes. (Source: https://hri.fi/en_gb/)
- B) **Communicative methods to increase participation quality:** Helsinki has also implemented an online participation tool named "Kerrokantasi ". It's a platform where city programs are posted, citizens can comment and voice their opinions, fostering dialogue and participation in city development. (Source: <https://kerrokantasi.hel.fi/>)

In Zurich, the use of Digital Twin technology falls under the "digital participation procedure facilitated by technological development." When involving a wide range of stakeholders, including businesses, residents, and visitors, in the city's development, the city uses "communicative methods to increase the quality of participation."

- A) **Digital participation procedure facilitated by technological development:** Although not a complete digital twin, Zurich has used technology to create a detailed 3D model of the city, which can be used for urban planning and development.
- B) **Communicative methods to increase participation quality:** Zurich has also been using mobile apps and online platforms to improve citizen participation. For example, the Züri wie neu (Zurich like new) app allows citizens to report problems like graffiti or broken infrastructure directly to the city. (Source: <https://www.zueriwieneu.ch/>)

In Dublin, implementing a Digital Twin for city planning and infrastructure management is a "digital participation procedure facilitated by technological development." Using digital platforms to include all residents' needs and aspirations is applying "communicative methods to increase the quality of participation."

- A) **Digital participation procedure facilitated by technological development:** Dublin's Smart City program includes IoT sensors around the city to collect data on various

aspects of city life, which could be seen as a step towards a digital twin. (Source: <https://smartdublin.ie/>)

- B) **Communicative methods as a way to increase the quality of participation:** Dublin City Council has implemented a platform called "Dublin City Dashboard"; this tool provides real-time information and visualizations of data collected by the city, and citizens can interact with this information, giving them a more active role in understanding and shaping their city. (Source: <http://www.dublindashboard.ie/>)

In each case, "digital participation procedure facilitated by technological development" describes the Digital Twin technology aspect and the technology aids stakeholders to engage in city planning and development more sophisticatedly. On the other hand, "communicative methods as a way to increase the quality of participation" refers to the use of digital platforms (enabled by the Digital Twin technology) for soliciting feedback, making decisions, and including various stakeholders in urban planning and city development processes. It has been argued that this application enhances stakeholder participation by fostering communication and engagement. While Digital Twin technology is promising in advancing urban planning and development, several gaps need to be addressed. These include the development of a measurable approach to assess the impact and effectiveness of the technology, upholding trust through robust security measures, open data, and maintaining data quality.

Moreover, there is a need to ensure functional effectiveness through establishing and maintaining a legal data environment, clear data ownership, governance and regulations, and the capacity to adapt to evolving technologies and societal needs. While Digital Twin technology is set to revolutionize city planning and development, it's crucial to take a step back and critically examine this tool's effectiveness. Ensuring that the technology is beneficial and serves the public good, creates value, provides insight, is secure and open, and produces high-quality data is fundamental. It's also paramount to focus on the technology's functionality, ensuring it can adapt and evolve as required and is based on a standard connected environment. This analysis has indicated room for improvement in several aspects of Digital Twin technology applications in planning. A more comprehensive, standard-based approach is needed to ensure the technology can effectively and sustainably fulfil its potential. The future of planning is exciting with the prospect of Digital Twin technology. Still, we must remain vigilant in ensuring that these technologies serve their intended purpose of enhancing the quality of life for citizens without compromising security, quality, or the capacity for evolution. The road to fully realized digital twins in planning is a journey, and these are steppingstones towards that

goal." The tables below are an analysis of Digital Twin implementation in the case studies based on the Gemini Principles that have been mentioned.

Table 1. Analysis of the “purpose” based on The Gemini Principles through the case studies resources.

<i>Purpose (Must have a precise aim)</i>			
	✓ Discussed in articles.		
	✗ Not discussed in articles.		
<i>Gemini Principles (Centre for Digital Built Britain, 2018)</i>	<i>Helsinki</i>	<i>Zurich</i>	<i>Dublin</i>
Public good: Must be used to deliver genuine public benefit in perpetuity	✓	✓	✓
Value creation: Must enable value creation and performance improvement	✓	✓	✓
Insight: Must provide determinable insight into the built environment	✓	✓	✗

It has been argued through the literature that this technology has privileges for society and the environment; it helps cities work smarter, create better traffic, and power systems, and adjust to climate change. Case studies almost support the first section of the Gemini principle; they show that this technology is helpful for city planning because it can run simulations and cut out repetitive tasks; for example, it can help us understand how climate change could affect cities.

While these studies suggest this technology is valuable, without straightforward evidence of its impact, such as quantifiable outcomes or demonstrations of increased efficiency, **how can we assess the actual contribution of this technology in improving participation in policymaking and climate change adaptation measures?**

"It's now more about measuring the tool's effectiveness than merely providing it."

Table 2. Analysis of the “Trust “based on The Gemini Principles through the cited case studies resources.

<i>Trust (Must be reliable)</i>			
	✓ Discussed in articles.		
	✗ Not discussed in articles.		
<i>Gemini Principles (Centre for Digital Built Britain, 2018)</i>	<i>Helsinki</i>	<i>Zurich</i>	<i>Dublin</i>
Security: Must enable security and be secure itself	✗	✗	✗
Openness: Must be as open as possible	✓	✓	✓
Quality: Must be built on data of an appropriate quality	✓	✓	✓

Based on the articles, data security “has not been broadly explained; sure, it is not the primary concern, but this is necessary to keep users' trust and uphold ethical standards.” Case studies show a push for openness, like in Helsinki's Open Cities Planner app; this app encourages citizen participation. But access to digital twins is usually limited for the public, hinting at the need for more openness. The case studies highlight the importance of high-quality data but do not provide specific steps to ensure this quality. They also point out potential gaps in data collection that need to be fixed, but it is unclear how often the data is updated or how comprehensive these updates are. In Dublin, Digital Twin is available online, letting citizens update and inform their data to aid urban planning tasks. In Helsinki, Urban Information Modelling (UIM) forms the Digital Twin base, allowing a full view of the city's lifecycle. However, the case studies do not clearly show how effectively the data collection and processing systems ensure high-quality data. Given the concerns raised over data security, accessibility, and quality assurance in the use of Digital Twin.

How can we balance safeguarding data security while promoting citizen participation and guaranteeing high-quality data in the continuous evolution of digital twins? To

further enhance their value in urban planning, **what concrete measures should be taken to address the apparent gaps in data collection?**

Table 3. Analysis of the “Function “based on The Gemini Principles through They cited case studies resources.

<i>Function (Must perform effectively)</i>			
✓ Discussed in articles. ✗ Not discussed in articles.			
<i>Gemini Principles (Centre for Digital Built Britain, 2018)</i>	<i>Helsinki</i>	<i>Zurich</i>	<i>Dublin</i>
Federation: Must be based on a standard connected environment	✓	✗	✗
Curation: Must have clear ownership, governance, and regulation	✓	✗	✗
Evolution: Must be able to adapt as technology and society evolve	✗	✗	✗

The case study of Helsinki reveals a compelling glimpse into utilizing a federated approach in Digital Twin technology, where data from diverse sources is seamlessly integrated into a unified city model. The importance of high-quality data is pointed out through the case studies, although specific measures ensuring data quality are not clearly detailed. Furthermore, integrating various data forms suggests operational compatibility within the Digital Twin models, but the methods and standards ensuring this compatibility are left unexplored; this brings us to a multifaceted, critical question:

What are the specific mechanisms needed to ensure high-quality data? And as we strive to merge data from various sources, **how can we establish and maintain operational compatibility within this Digital Twin?** Furthermore, **what would a comprehensive framework for data standardization look like to ensure seamless integration and interoperability across diverse data sources and types in the Digital Twin context?**

5.2. Analyzing the case studies using the Information Value Chain and linking it to the Gemini Principle

This section shifts to the case of Digital Twin in Helsinki, Zurich, and Dublin with the lens of the information value chain (The IVC framework offers a systematic approach to understanding how data can be distinguished into valuable, actionable insights, influencing decision-making, and promoting improved outcomes.) and in which part expert and citizen participation happened by demonstrating which part of the IVC framework corresponds with Gemini principle.

Diagram 1. showing in which part of the information value chain expert and citizen participation occurs and which part of the IVC has correspond with which part of the Gemini principle. Source: drawn by the author.

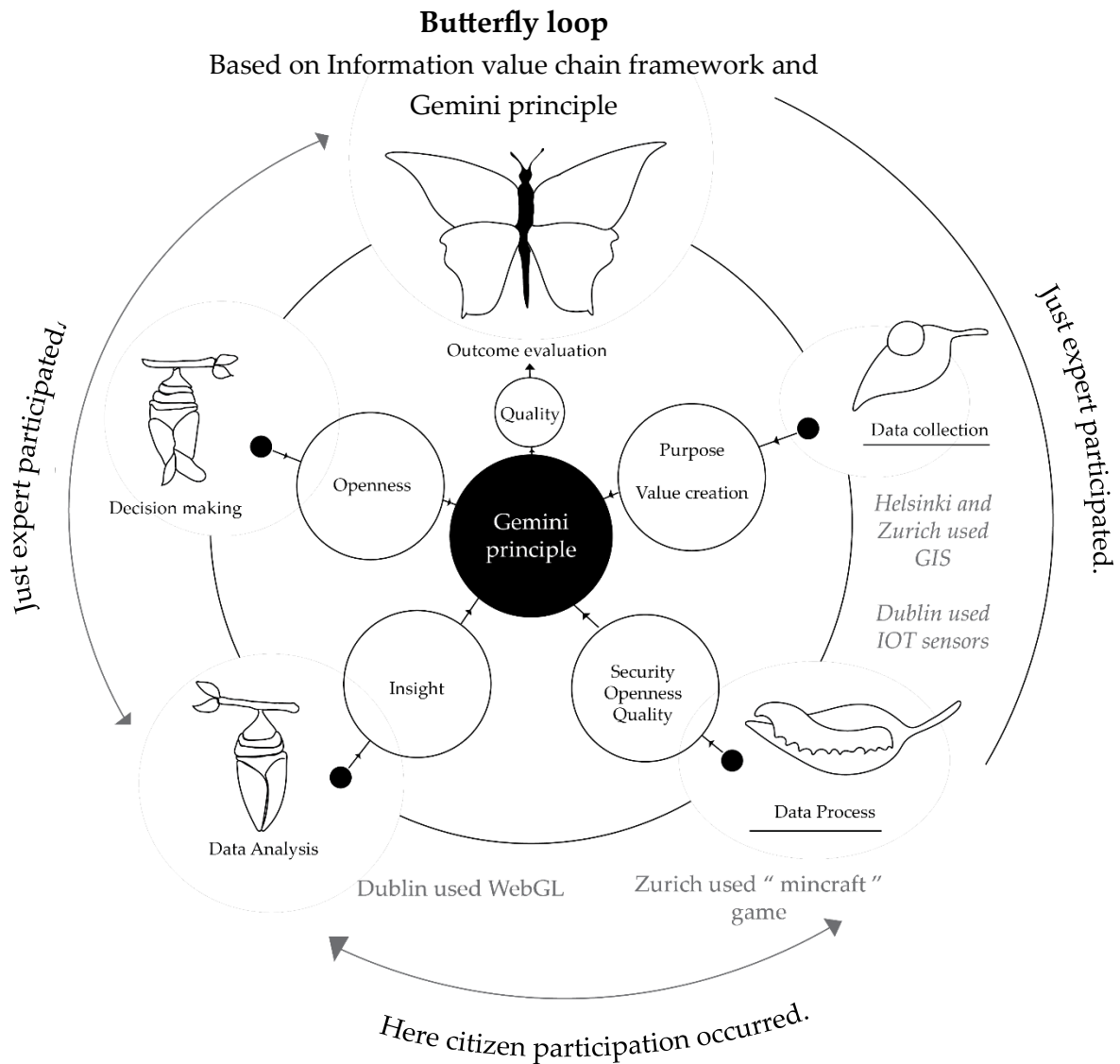


Table 4. Analysis “Data collection” based on The Information Value Chain and Gemini principles.

<i>Data Collection</i>	
<p>The Information Value Chain <i>(Centre for Digital Built Britain, 2018)</i></p> <p>This initial stage is where raw data is gathered from various sources. The type of data collected can range widely, from demographic data to environmental indicators, infrastructure details, and more. The goal is to capture a comprehensive, accurate picture of the objects.</p>	<p>The case study analysis</p> <p>In the case studies, data collection comes from diverse sources, including GIS, 3D modeling, existing infrastructure, and even public participation. This raw data is the fundamental base upon which digital twins are created. For instance, in the Hervanta case, the data is used for improving self-driving car studies, whereas, in Kalasatama, data is connected to enhance citizen participation in urban planning through the Open Cities Planner application. But here is the question that should ask;</p>
<p>Gemini Principles <i>(Centre for Digital Built Britain, 2018)</i></p> <p>The corresponding Gemini Principles include Purpose and Value Creation. In this context, the Purpose indicates the need to collect data that serves the public good, such as about buildings, infrastructure, or environmental conditions. Value Creation underscores the need for comprehensive, high-quality data, as its absence may put at risk the value chain stages.</p>	<p><i>Does the existing data collection procedure fully encapsulate the broad landscape required for a precise Digital Twin as it has been advocated, and are there any concealed sections in our data view that need to be addressed?</i></p>

Table 5. Analysis “Data processing” based on The Information Value Chain and Gemini principles.

<i>Data processing</i>	
The Information Value Chain <i>(Centre for Digital Built Britain, 2018)</i>	The case study analysis
<p>Once the data is collected, it must be processed into a usable format; this involves cleaning the data to remove any errors, inconsistencies, or redundancies and then transforming it into an easily analyzed form. Depending on the nature of the data and the project's objectives, this might involve creating visualizations, sorting data into categories, or applying mathematical or statistical transformations.</p>	<p>The IVC framework points to data processing - refining our raw data, like a sculptor transforming a rough stone into a more detailed statue. For example, Helsinki gave a chance to this process through Urban Information Modelling (UIM), integrating 3D modelling and Geographical Information System (GIS) data, thereby setting the stage for the city-level Digital Twin.</p>
Gemini Principles <i>(Centre for Digital Built Britain, 2018)</i>	
<p>The corresponding Gemini Principles are Security, Openness, and Quality, which all fall under the Trust category. Ensuring the Security of the data during this stage is vital. Openness refers to the transparency in the methods of processing used, and Quality refers to maintaining high standards in the data processing.</p>	<p><i>But as has been admired by many speakers, it is essential to know- what measures were taken to ensure the accuracy and standardization of the data during its transformation?</i></p>

Table 6. Analysis “Data Analysis” based on The Information Value Chain and Gemini principles.

<i>Data Analysis</i>	
The Information Value Chain <i>(Centre for Digital Built Britain, 2018)</i>	The case study analysis
The processed data is then analyzed to extract meaningful insights; this might involve identifying patterns or trends, testing hypotheses, or applying complex statistical or machine-learning models. The exact methods used depend on the nature of the data.	With the data processed in the case studies, various applications have been introduced - analyzing city views, wind conditions, microclimates, and traffic, all aiding urban planning decisions. Yet, the case studies are like a closed book regarding the analytical methods and techniques used.
Gemini Principles <i>(Centre for Digital Built Britain, 2018)</i>	<i>Hence, we must ask - are current data analysis techniques akin to developing actionable insights that can guide effective decision-making?</i>
This stage correlates with the Gemini Principle of Insight, which seeks to improve our understanding of the built environment.	

Table 7. Analysis “Decision Making” based on The Information Value Chain and Gemini principles.

<i>Decision Making</i>	
The Information Value Chain <i>(Centre for Digital Built Britain, 2018)</i>	The case study analysis
<p>The insights obtained from the data analysis are used to inform decision-making processes. These decisions can span various areas, from operational changes to policy formulation. The goal is to use the data-derived insights to make more informed, effective decisions that align with the entity's or system's objectives.</p>	<p>The case studies have shared a few glimpses of how Digital Twin technology contributes to policymaking. But we still lack clear outlines of decisions directly influenced by the Digital Twin technology and where participation has played a pivotal role.</p>
Gemini Principles <i>(Centre for Digital Built Britain, 2018)</i>	<p><i>So, the question stands - can we find tangible evidence of how Digital Twin technology has improved urban planning decision-making?</i></p>
<p>The decision-making step in the IVC aligns with the Gemini principle of 'Interoperability.' At this stage, the analyzed data is used to make informed decisions. The function here implies the capability of various systems to use this information, ensuring that the data can be interpreted and utilized across different domains for effective decision-making.</p>	

Table 8. Analysis “Outcome Evaluation” based on The Information Value Chain and Gemini principles.

<i>Outcome Evaluation</i>	
The Information Value Chain <i>(Centre for Digital Built Britain, 2018)</i>	The case study analysis
<p>The final stage in the Information Value Chain is to evaluate the decisions' results, assessing whether the findings have led to the desired outcomes and measuring their impact. The evaluation provides feedback that can inform future data collection, processing, and analysis, creating a cyclical continuous improvement process. In essence, the Information Value Chain depicts the journey of data from collection to action, showcasing the transformative power of data when effectively managed and utilized.</p>	<p>The case studies make bold claims of increased efficiency in traffic and power management, thanks to the implementation of Digital Twin technology. But where is the evidence? Where are the numbers? Outcome evaluation is essential to understand the impact and value of the decisions made.</p>
<p>Gemini Principles <i>(Centre for Digital Built Britain, 2018)</i></p>	<p><i>Therefore, we must ask - how we can measure and quantify the effectiveness of decisions influenced by Digital Twin technology?</i></p>
<p>Finally, the outcome evaluation stage of the IVC reflects the 'Quality' principle of Gemini; this involves the measurement and assessment of the decisions made based on the data analysis, ensuring the effectiveness of those decisions, thereby validating the quality of the data and the entire process. By mapping the IVC to the Gemini principles, the process of transforming data into improved decisions for enhanced outcomes can be well-structured, ensuring that each step contributes to the overall value and effectiveness of the system.</p>	

Using the Information Value Chain framework as a compass through the case study, we have been able to critique the potential of Digital Twin technology in urban planning. However, the discussion has not been without its challenges. Certain areas within our IVC framework have proven to be less thoroughly charted by the case studies, which has, in turn, given rise to some obstacles we have faced and discussed in this chapter. Identifying these complicated points is not a cause for despair but rather a request for further exploration. In fact, by taking up this challenge, we open the possibility of enhancing the power of Digital Twin technology in urban planning. With a more particular data collection strategy, more safeguards during data processing, a more detailed understanding of data analysis techniques, more explicit examples of decision-making, and quantifiable outcome measures, we could maximize the potential of this remarkable technology. Indeed, we are left with a sense of anticipation and curiosity. Are we ready to seize it, address the challenges and chart a course into a future where Digital Twins guide us towards better and more informed decisions? That is the question we must carry with us as we continue into our most unpredictable world.

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Digital Twin has been argued that it could help improve various city tasks such as traffic management, adapting to climate change, and managing power systems distribution. These Digital Twin technologies allow for detailed studies of essential city projects and testing of recent technologies. For instance, Helsinki's Digital Twin was used to study a public transport project and test self-driving vehicle technologies, which saved money compared to traditional testing methods. In another district in Helsinki, Kalasatama, the Digital Twin was used in the Open Cities Planner project. As has been argued, this project aims to help citizens understand Digital Twin data and encourages them to participate, making it more transparent. This information was gathered through interviews with urban developers and Digital Twin technology company representatives. It was found that having a robust digital city model and data infrastructure is essential for quick and effective urban simulations. It has been pointed out that this is why Urban Information Modelling (UIM) was introduced to help create digital twins of entire cities.

However, despite digital twins' potential in urban design, various organizational and technical challenges hinder their widespread usage; these include unsupported processes for data generation in digital formats, a lack of perceived added value from new digital technologies, and the need for changes in organizational culture. With technological advancements, these obstacles are gradually being overcome, enabling the processing of large datasets, and enhancing connectivity between the virtual and physical city. Another project mentioned before, the Digital Twin program in Zurich, was created following the Federal Act on Geoinformation and the INSPIRE Directive. This initiative aims to establish a comprehensive, three-dimensional digital model of the city, thereby enhancing spatial data infrastructure and impacting several sectors by integrating a third dimension into the digitization and processing of space. This revolutionary project promotes citizen engagement and has various utilities, including applications in environmental modelling, energy potential analysis, and urban planning.

In contrast, it has been argued that the Dublin Docklands Digital Twin technology is an effective tool for urban planning simulations and studying public feedback on proposed changes. It promotes citizen participation and interaction through a publicly accessible 3D model of the city, making policy and urban development programs more transparent. However, challenges such as a lack of support for data production in digital formats and a perceived lack of added value from recent technologies persist. The analysis of Digital Twin technology usage and impact on urban planning, as discussed, has been structured around the Gemini Principles, including Purpose, Trust, and Function. Although digital twins hold exciting potential for urban planning, there are significant gaps, including

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data security, citizen participation, high-quality data, and data standardization framework. Thus, while using digital twins is promising, it is crucial to recognize and address their limitations. Digital twins, the fresh players in the tech field, are marketed as a powerful tool for getting more people involved in the decision-making process. This idea is not just a catchy phrase and is not as simple as it sounds. It has been argued that what sets digital twins apart from other technologies is their ability to create a real-time, digital version of something tangible, like a mirror that does not just reflect what's happening now but can show different possibilities. They can help us collaborate more freely, like a team working on a project with a clear blueprint.

Imagine for a moment the complexity of a modern city. The busy streets, the high-rise buildings, the sprawling parks, and the bustling markets - a confluence of many different elements, each with its own unique attributes and functions. Managing such a complex entity requires a prominent level of sophistication. This is where the concept of a 'digital playground' comes into play, bringing with it the promise of an efficient and effective tool to manage urban spaces - the Digital Twin technology. Digital Twin technology can be visualized as a dynamic digital replica of a physical entity, city, or system. This allows us to simulate, analyze, and understand various aspects of the entity, thereby helping us make informed decisions about its management. Technology offers a platform where we can explore different ideas and solutions to various urban problems before implementing them in the physical world. It provides a glimpse into the potential outcomes and consequences of our decisions, hence reducing the risks associated with the decision-making process.

On the surface, Digital Twin technology appears to be an innovative solution. It presents a compelling image - a dynamic digital replica of the physical entity, city, or system, capable of simulating, analyzing, and understanding the diverse facets of the city. The technology posits itself as a digital platform to explore and experiment with different urban solutions before translating them into reality. This approach provides an overview of the potential outcomes, thus reducing the risks associated with decision-making. While the benefits of such technology seem apparent, it is critical to approach it with a balanced perspective. As with any technology, Digital Twins come with their own set of challenges and limitations. First and foremost, the process of creating a Digital Twin is itself a complex task, involving the digitalization of entire cityscapes down to the closest detail. This process demands vast resources and time, which may be beyond the capacity of many city administrations, especially those of developing or under-resourced cities.

Furthermore, while Digital Twin technology may provide a detailed representation of the city, it is only as accurate as the data it is based on. This calls for a constant influx of up-to-date, accurate, and comprehensive data, which is a formidable challenge in itself. In cities where data collection infrastructure is lacking or non-existent, maintaining an

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accurate Digital Twin would be an uphill task. The implementation of Digital Twin technology also raises concerns about data security and privacy. The technology would require collecting and storing vast amounts of data, some of which could be sensitive or personal. The potential misuse of this data or a breach in the system could have serious implications. Technology's promise of reducing risks associated with decision-making can be a double-edged sword. While it can indeed provide insights into potential outcomes, it could also result in an over-reliance on technology for decision-making. The technology is fallible, and mistakes or misinterpretations can lead to significant problems. Furthermore, technology cannot account for all real-world variables, unforeseen circumstances, or the organic evolution of cities.

Digital Twins, in theory, could democratize urban planning. They offer a platform where citizens can engage with and understand complex urban systems and the potential impacts of various urban development projects. By creating an accurate and interactive representation of the city, these models can facilitate a more transparent and inclusive urban planning process. Citizens can visualize proposed changes, understand their implications, and provide feedback, fostering a more participatory decision-making process. However, it is important to critically consider to whom this technology is truly serving. Digital literacy and access are not evenly distributed across societies, leading to disparities in who can interact with and influence these digital models. Therefore, the potential of Digital Twins to democratize urban planning might unintentionally widen existing social inequalities if these disparities are not addressed. Furthermore, the representation of cultural aspects in the Digital Twins can also be challenging. Cities are not just a collection of buildings, roads, and infrastructure.

They are also a reflection of their inhabitants' culture, history, and shared experiences. While it might be straightforward to model physical aspects of a city, it is far more challenging to accurately represent and maintain the cultural aspects, such as historical landmarks, cultural events, and community spaces that hold significance for the local population. Finally, there are significant ethical considerations to consider. Digital Twin technology relies heavily on data, including data about citizens and their behaviors. It is critical to ensure that this data is used responsibly and that the privacy rights of citizens are respected. Furthermore, there is the question of who gets to make decisions about what is included in Digital Twin and how it is used. There must be ethical guidelines in place to prevent misuse of this technology and to ensure that it truly serves the public's best interest.

The concept of a Digital Twin embraces physical infrastructure such as buildings, roads, and utilities, as well as environmental factors like weather patterns and air quality. However, social aspects like public sentiment, cultural values, and human behavior are

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challenging to capture and integrate into the Digital Twin framework. These are critical elements that greatly influence urban planning and policymaking but are often neglected due to the complexity involved in modeling them. When we build a Digital Twin of a city, we inevitably face limitations in the number of factors that can be included in the model. The omission of certain factors could result in an oversimplified model that does not accurately represent the complexities of the real world. However, it is crucial to acknowledge that Digital Twins, like any other technology, are not perfect. They have their limitations and challenges. Technology has been hailed as a medium to increase public involvement in the decision-making process, promoting transparency and inclusivity. The concept of having a digital representation of a city that can be manipulated and tweaked according to citizens' feedback sounds promising. Still, in practice, the application of Digital Twins faces significant hurdles that prevent it from being the ultimate solution for urban planning.

While Digital Twin technology holds immense potential, it is essential to temper optimism with reality. No solution, no matter how groundbreaking, is without its flaws. The application of Digital Twins in urban planning, despite being feasible in theory, is contingent upon several factors. For instance, the creation of Digital Twins depends on a limited set of variables and processes. These variables might not fully encapsulate the range and depth of real-world complexities, especially when it comes to social issues. This disagreement between the representation in the digital model and the reality of the city can result in a lack of effectiveness when it comes to involving citizens in the urban planning process. It is vital to remember that while the Digital Twin presents a more efficient and transparent approach to urban planning, it may not be as inclusive or comprehensive as we would like it to be. Despite the potential for Digital Twins to revolutionize urban planning, we must continue to explore and address these shortcomings to ensure that they serve as an effective tool for city planning.

In conclusion, while Digital Twins offer a tempting glimpse into a future where urban planning is efficient, data-driven, and inclusive, we must also recognize and address their limitations. They are not a panacea for all urban planning issues, but with continual refinement and development, Digital Twins can serve as a valuable tool in the toolkit of urban planners and policy makers. By recognizing and addressing these challenges, we can maximize the potential benefits of Digital Twin technology, while also fostering a more inclusive and participatory urban planning process. Beyond what has been said it is vital to imagine that each city is like a person, and it is important to know that is it mature enough to grasp what is being said or is just a newborn infant which needs time to learn and adapt. Digital twins seem promising to get more people involved in making decisions. They differ from other technologies we have seen before and are advertised with innovative features, offering a more transparent, inclusive way of making decisions.

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But it is important not to get optimistic. We must know their limitations and not get lost in the hype. As technology grows, we must keep a balanced view, recognizing the good it can do and being ready for the challenges it might bring. We should question ourselves - are we truly ready for the future, or is 'digital twin' just a marketing catchphrase suggesting that 'the future is on your screen'?

*As my defence to what I have said so far, I refer you to the title of an article published by Kenworthy, J. (2012) named "**Don't shoot me I'm only the ... planner** (apologies to Sir Elton John). "*

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