Co-creative Twinning: Participatory Practices and the Emergence of Ownership in Digital Urban Twins

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Abstract. This paper presents a unique case study of co-creative modelling in a digital urban twin, exploring the inclusion of diverse concerns, stakeholders, and practices in the building of a complex socio-technical system. It does so by employing a co-creative methodology for modelling complex socio-ecological processes in the Connected Urban Twins Project (CUT) Hamburg. The methodology involves early engagement of stakeholders during problem formation and collaboration through a series of co-creation workshops. Through the examination of this collaborative effort, this research aims to describe the relevant factors and practices associated with co-creative twinning, particularly in the context of engaging diverse stakeholders in building socio-technical systems. By analysing this process, valuable insights and lessons will be derived for twinning experts seeking to involve citizens and other stakeholders in their twinning projects. Furthermore, this research critically reflects on the emerging interactions and outcomes of the twinning process, discussing the feasibility of the methodology in terms of enhancing transparency, building trust, reconfiguring knowledge and stakeholders in digital urban twins, as well as supporting collective decision-making and ownership. In order to support twinning experts in co-creative efforts, the research derives lessons learned suitable for involving diverse stakeholders in co-creative twinning efforts.

Keywords: Digital Urban Twins, Co-creation, Participatory Modelling, Participatory Digital Urbanism, Sustainability

1 Introduction

In recent years, digital urban twins (DUT) have become crucial components of digital cities. While a formal definition of DUT is still lacking, it is generally acknowledged that a digital twin is understood as a virtual representation of a physical entity, driven by data and utilised for prediction, monitoring, control, and optimisation (Clemen *et al.*, 2021, pp.

45). This can have the form of, but is not limited to, 3D-model of cities, VR applications in planning, or urban data platforms. Batty (2018, p. 1) suggests that any such system resembling the operation of another is a model. And models are abstractions – a representation of the system that does not aim to replicate the original in the same level of detail. This process of representation thus is a practice of constructing a twin through the inclusion of some data and exclusion of other.

However, existing definitions overlook the knowledge and data included in the twin and the stakeholders involved in its construction. Solman *et al.* (2022) argue that some concerns, especially those related to social aspects, are often excluded from twins due to their complexity. Batty (2018) further supports this notion, stating that these models rarely incorporate the social and economic functions that shape a city. Consequently, defining a twin as an object fails to recognise *twinning* as an active process involving decisions and actions regarding its design, and the inclusion and exclusion of perspectives, knowledge and data.

To enable broader stakeholder participation and diverse practices, Solman *et al.* (2022) propose examining twinning processes from a co-creative standpoint, emphasising engagement and deliberation. Similar arguments are echoed in the model development community, advocating for multi-stakeholder modelling approaches to incorporate diverse perspectives in socio-technical systems (van Bruggen at al., 2019; Tolk *et al.*, 2022). Despite increasing calls for co-principles in modeling, empirical case studies and best practices in Digital Urbanism remain limited.

This research focuses on the co-creative twinning of complex social functions within a DUT using a participatory modelling approach. Specifically, the paper explores ongoing research in Hamburg's evolving modular digital urban twin infrastructure. It builds upon established participatory modelling frameworks in resource management and applies them to the development process of the Connected Urban Twin project. The case study involves representatives from public administration, civil society, and the private sector, who actively participate in co-creation workshops. The goal is to design a model addressing climate protection and social equity, specifically gentrification processes in Hamburg triggered by climate protection measures.

To guide this investigation, the following research questions are addressed:

Q1: How can complex socio-ecological topics be effectively modelled in a Digital Urban Twin through the active involvement of a diverse set of stakeholders?

Q2: Which new practices emerge from co-creative twinning, and how does this facilitate the emergence of agency, trust and ownership?

The paper is structured as follows: It begins by introducing the case study and clarifying key concepts. Next, the workshop methodology and co-creation process are presented.

The results section analyses the emerging twinning practices and challenges encountered during the co-creative modelling process, based on recently concluded workshops. The discussion section reflects on the research goals and presents preliminary conclusions.

2 Literature and Methods

2.1 Case Study

Prior to selecting the case study, the researchers had to define an umbrella topic leading the experiment. We select two seemingly opposing public values for the umbrella topic: climate protection and social cohesion. In bringing these topics together, we made it possible to expose safely the tension between their circumstances and discover hidden but valuable strategies in addressing and planning for both values.

Given its existing digital infrastructure, open data laws, and ongoing digitisation initiatives, Hamburg was selected as the case study for this research. It ranks highest among German smart cities, as indicated by a 2021 index (Statista, 2023a). With its population size of 1.89 million (Statista, 2023b) and commitment to achieving carbon neutrality by 2045 (Hamburger Senat, 2022, p. 16), Hamburg provides an ideal context for investigation. Additionally, the city has implemented policies like the social preservation ordinance (Soziale Erhaltungsverordnung) to safeguard residents from displacement in their neighbourhoods.

The CityScienceLab in Hamburg serves as a living laboratory[52], collaborating with the city's public administration to develop and test digital urban technologies. One notable research project conducted by the CityScienceLab is the Connected Urban Twins project (CUT), which has received substantial federal funding of 21 million Euros and stands as one of Germany's largest smart city initiatives. In the CUT, the cities of Hamburg, Leipzig, and Munich are working together to establish a modular digital infrastructure that enables the creation of what-if scenarios to enhance governance processes (Schubbe, 2023). As part of this endeavour, a series of real-world experiments are being conducted to test technologies with a diverse range of stakeholders.

This research is situated within one of these real-world experiments, comprising a four-month experimentation phase in the first half of 2023, preceded by a preparatory phase

[52] Living laboratories, here, are understood as an emerging instrument in innovation policy that tests new sociotechnical arrangements in situ and at a meso-scale, reconfiguring societies (Engels *et al*., 2019). These test settings are characterized in their reciprocity with the environment which they modify (Marres and Stark, 2020).

of approximately three months. Noteworthy collaborators for this research include the project partners involved in the CUT (see acknowledgements).

2.2 Literature

Science and Technology Studies provide analytical resources to understand how technologies can be co-created and with what effects. A great deal of Participatory Design and Computer Supported Cooperative Work research is directed at designing computer-based systems, with interdisciplinary teams following rapid prototyping approaches. The field emerged first in private sector work environments as a reaction to the disruptive force of technological innovations, and aimed at strengthening workers' control over their work processes (Zimmerman and Forlizzi, 2014; Kensing and Blomberg, 1998). Likewise, user-centered design practices and Design Thinking emerged in Human-Computer Interaction, focusing on iterative design and development processes that put users and their needs at the center in order to ensure usability and uptake of products (Ghaoui, 2006; Stembert, 2017). While these practices have oftentimes focused on building prototypes, seldomly going beyond the early analysis and design activities, others have actively involved users throughout the entire development phase with the goal of developing general, tailorable software products. Such are the Cooperative Experimental System Design (CESD) school (Grønbæk *et al*., 1997 & 2002) and the Participatory Modelling (PM) Community (Abrami *et al*., 2021). The latter involves non-scientist stakeholders early in the modelling process, during the preparation and organisation stages, all the way to the follow-up stages such as dissemination and evaluation.

While CESD and PM approaches have been well established and documented in Human-Computer Interaction and Socio-Ecological Settings, case studies engaging these approaches in digital urbanism remain sparse. Despite an increasing amount of literature calling for a participatory approach to the Digital City, participatory digital urbanism is still oftentimes limited to the design analysis phase pre-development, or a co-creative delivery of services and products post-development, and is oftentimes facing the challenge of difficult integration into procedures of local governments (Harvey *et al*., 2022).

By disregarding the construction of urban technologies, participatory digital urbanism misses the opportunity to engage with the wider implications of participatory processes within socio-technical systems, failing to meaningfully address its performativity and constructedness, and to transform scientific, democratic and political orders (Latour, 2007; Chilvers and Kearnes, 2020; Felt *et al*., 2017).

It is this the goal for my research, engaging in the co-development of urban technologies with a diverse set of stakeholders through a relational perspective, reflecting on the constructed, emergent, and interconnected realities of digital participatory urbanism. We look at participation not just as a starting point for, or an outcome of, the development of urban technologies, but as the very means to build these. Thus, this research expands on Solman *et al*.'s (2022) call for scientists to engage in the co-creation of digital twins, learning about the practices of engagement and deliberation that digital twins can foster.

2.3 Methodology

By adopting the perspective of Solman *et al*. (2022), which emphasises the inclusion of diverse stakeholders in the early stages of the development process, this research places co-creation at the centre of digital urban transformation. Co-creation offers several advantages, such as accessing various levels of knowledge and uncovering latent and implicit needs and desires of participants (Thoneick *et al.*, 2021). It also facilitates collaboration between groups that typically wouldn't work together, fostering a shared understanding, safe spaces for sharing, and empowerment of minority perspectives (Sanders and Stappers, 2008).

Co-creation can be defined as a collaborative process involving the active participation of multiple stakeholders in the creation, design, and development of new ideas, services, or products (Van Praag, 2021). It recognises the significance of engaging city residents, policymakers, urban planners, technology developers, and other relevant actors to collectively shape and contribute to the design, implementation, and utilisation of digital twins. In recent years, these concepts have evolved toward more user-centric and co-creative approaches, particularly in technology development, where users are regarded as experts of their experiences. During co-creation, collaborators jointly define the problem and create the solution, uncovering latent knowledge that informs system architecture requirements (Stembert, 2017).

While the benefits of citizen involvement in smart city initiatives are widely acknowledged, disagreements remain about what constitutes „good" engagement (Felt *et al*., 2017), and the absence of a solid conceptualisation of participation, co-production, and co-creation can result in superficial forms of engagement that fail to empower citizens, capture diverse perspectives and knowledge, and redistribute decision-making power. Our definition draws on several approaches in the field, delineating four essential conditions for a reflexive and transformative practice that we call co-creative twinning.

A first essential condition are the **twinners** involved: Co-creative twinning entails collaboration between the designers and implementers of digital urban twins and the beneficiaries of these models. It involves citizens contributing their input to create the

product (Ostrom, 1996; Boyle and Harris, 2009; Meijer, 2012). In the context of our co-creative twinning research, we involve various stakeholders in the creation and evolution of digital models of urban environments. We engaged with planning authorities, critical urban activists, civil society actors from the fields of climate urbanism and rental justice, representatives of proprietor's and tenants' organisations.

The second essential condition are the **practices** of co-creative twinning. Building on work in public administration research, we see co-creative twinning as an enhanced form of participation (Bovaird, 2007) in which citizens actively engage in the design, implementation, and evaluation of the Digital Urban Twin. Co-creation emphasises the collaborative efforts among diverse actors, including researchers, practitioners, users, and other relevant parties. This research made an active attempt to move beyond deliberative practices, actively co-creating the digital city model by engaging with concepts of the socio-technical system, engaging with digital tools, reading code snippets, and building the models literally with their own hands on a screen.

A third condition is the emergence of **agency** in the twinners by enabling twinners to actively contribute to the design and implementation of public initiatives. The notion of agency is closely tied to power – spatial agency implies that it is possible to engage transformatively with structure, being able to intervene in the world with the effect of influencing a specific process or state of affairs (Awan, Schneider and Till, 2011). In our research, we examined agency as a way to share decisional power on the aspects included in the modelling process and shape the process according to participants' needs and wishes.

A fourth condition of co-creative twinning is the **reflexivity** of the process. Coproductionist STS perspectives have started to consider participation as objects of study and intervention of their own right, seeing participation as a constitutive of science and democracy rather than outside of it (Latour 1993; Chilvers and Kearnes, 2020). Committing to reflexive experimentation means ongoing responsiveness to emergence, openness about the uncertainties of participation, and attending to exclusions and inequalities within wider ecologies and systems of participation (Chilvers and Kearnes, 2020).

Our research in co-creative twinning, then, includes (1) examining the twinners involved, their needs and interests and the means of engaging a diverse set of stakeholders, (2) detecting emerging twinning practices and the reconfiguration of knowledge, (3) investigating agency and the sharing of decisional power, and (4) analyzing the process in regards to openness and reflexivity. By adopting this framework, the analysis provides a comprehensive understanding of co-creative twinning and its underlying elements.

2.4 Research Design

Following the above mentioned conceptualisation of co-creative twinning, the research expands on existing participatory modelling frameworks established in resource management, and designs and applies a custom-made methodological framework to the twinning process. The experimentation phase took place from February through May 2023 and consisted of four consecutive workshops. The first happened online via a video conferencing tool, aided by an online whiteboard tool for note taking. The other three workshops took place offline, in the location of the CityScienceLab in Hafencity Hamburg, using a Digital Multi Touch Table (Fig. 1). The research laboratory has a large experience space where workshops can be held, and its character as a non-governmental research institute helped to create a somewhat neutral space for participants from governance and activism. In the following, two intersected research strands are described. The first is the co-creative modelling methodology aiming at a collaborative twinning process, which is in both parts research methodology and case study description; the second is the methodology for data collection and analysis.

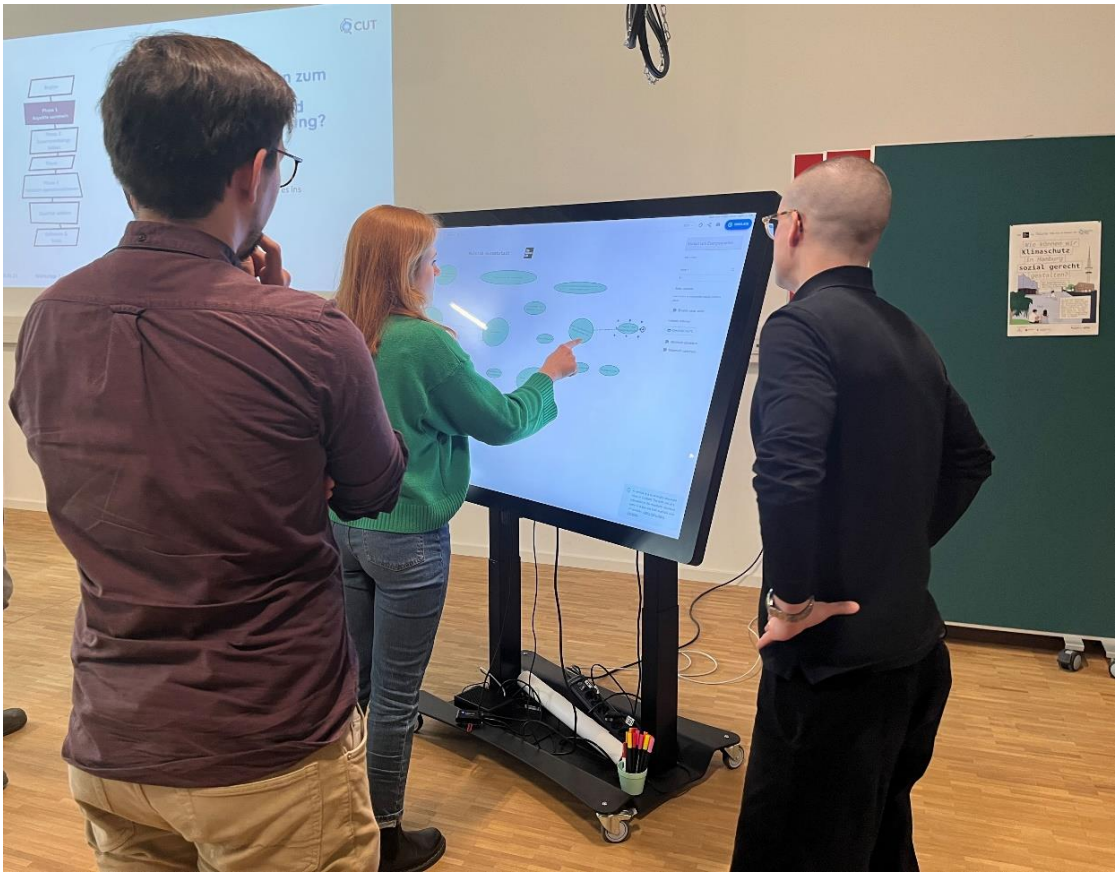

Figure 1: Workshop situation: Participants mapped aspects in an online tool using a Multi Touch Table.

2.4.1 The Co-creative Modelling Process

The goal formulation for the experiment phase was to design, implement and test a co-creative modelling workshop methodology that would invite diverse stakeholders to the process. In parallel, technological development was taking place and was informed by decisions made in the modelling workshops. These two iterative processes intertwined and iteratively conjoined along the timeline (Fig. 2), however, this research shall focus on the co-creation process. More information on the development process can be found in (Herzog, 2023).

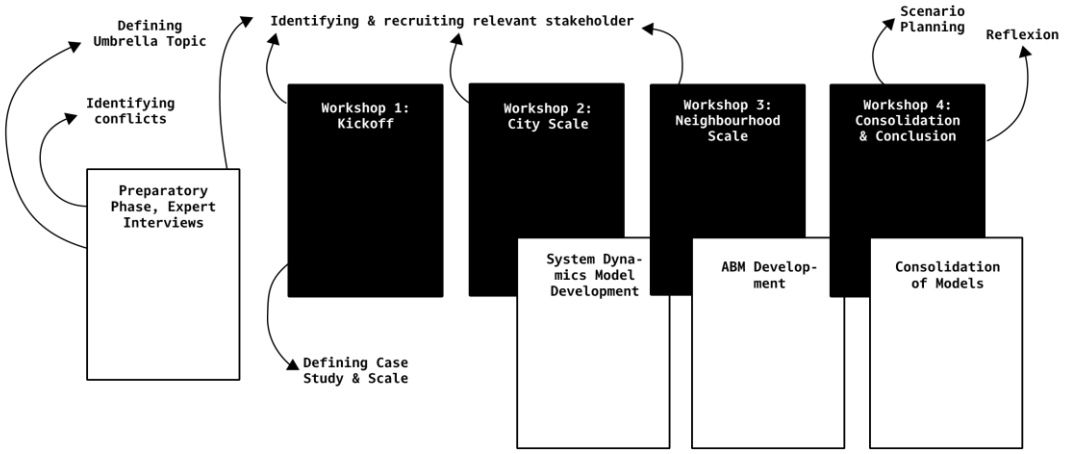

Figure 2: The experimentation process oscillated between planning and development phases conducted by the researchers (white), and workshop phases with stakeholders (black).

The twofold research process called for a flexible approach that would adapt in course of action based on participants' decisions and expressed needs, wishes and concerns. Cornerstones of the co-creation process were four workshops (Fig. 2), of which each had ramifications for the following workshop. The decision on an umbrella topic had consequences for the city-scale, the city-scale had an impact on the model type, the model type influenced the co-creative methodology. By not predefining topic, scale, model type, and methodology, we created an open-ended process that allowed for participants to have influence on the problem framing, the methods and the twinning procedure.

Voinov and Bousquet's (2010, 1273) stages of participatory mapping[53] helped frame activities, as they define elements of the modelling process that can be rearranged in

[53] The stages of a participatory modelling process are: identify project goals, identify and invite stakeholders, choose modelling tools, collect and process data, discuss system & build conceptual model, run model & discuss results, discuss and define scenarios, analyze model & discuss improvements, present results to other stakeholders and decision makers. These stages include loops back and forth, can

order. In our participatory modelling process, these stages were conjoined into (1) a preparatory phase to define the umbrella problem in a student workshop by building Wicked Questions[54] merging two opposing topics together, resulting in the topic of climate protection and social equity, and identify conflicts within that umbrella topic through informal expert interviews, (2) the Kickoff workshop, where a specific case study was selected within the larger umbrella topic of climate protection and social equity, and decisions were made on the scale the simulation models should represent and the questions they should address, (3-6) the development phase of two models of Hamburg that cover the aspects and their relations identified by the stakeholders, (7) simulation of various scenarios with policy levers and reflecting together with the research team on the simulation results and the feasibility of such systems in order to support their practice, and (8) consolidating both models and integrating them in the wider context of the Digital Urban Twin. Identifying relevant stakeholders involved in that realm and recruitment through a snow-ball system was an ongoing activity throughout the process.

The stakeholder selection is a crucial factor in co-creative processes as it significantly influences the outcome of the designed model, product, or service. In our study, stakeholder acquisition was an ongoing process. It involved desk research, personal recommendations, and existing networks. Expert interviews were conducted to gain insights into climate protection and social equity, followed by a mapping of relevant stakeholders. The umbrella topic of climate protection and social justice was defined early in the process. For stakeholder selection, we defined **areas of expertise**: for the *administrative and legal* view we selected the local government ministries for planning, housing, nature and climate protection and members of the district advisory board, for the *planners'* view we selected district planning offices and private planning companies, for the *aggregated perspectives of tenants', climate protection and social justice* we selected non-governmental organizations in the realms of coding and fab labs, environmental and climate protection, tenant counseling and housing associations, and for a representation of *directly afflicted perspectives*, we selected tenants and property owner associations as well as neighbourhood initiatives. Representatives of these areas of expertise were then identified either through desk research or personal networks, and subsequently contacted via email or telephone. The aim was to have at least one representative from each area of expertise present in each workshop, however this goal could not always be achieved. Some participants represented several perspectives (a lawyer in tenant counselling can at the same time be a person directly afflicted by push-

be reordered, and don't necessarily all have to be met within one participatory modeling process. (Voinov and Bousquet 2010)

[54] Wicked Questions are a method of a collection of group processes and methods named *Liberating Structures*. Groups can use Liberating Structures to facilitate innovative collaboration and radically change interaction. More information on https://www.liberatingstructures.com/

out dynamics in their neighbourhood), however they were counted in their primary role (Fig. 3). Stakeholders were also identified through professional and personal networks of project partners and researchers. A snowball system was employed, with participants who agreed to participate suggesting other relevant stakeholders.

	Participants	Areas of Expertise
Workshop 1	9	admin & legal: housing (2), planner (3), tenant counsellors (2), urban justice activists (2)
Workshop 2	3	admin & legal housing (2), tenant counsellors (1)
Workshop 3	6	admin & legal housing (2), tenant counsellors (2), direct tenant (1), direct landlord (1)
Workshop 4	5	admin & legal housing (3), tenant counsellors (2)

Figure 3: Participation varied between the workshops with highest attendance by members of the housing administration and tenant counsellors. Climate protection representatives had been invited but were unable to attend any of the workshops.

The **first workshop** was framed as a 2-hour online kickoff workshop. It aimed at bringing together the working group and presenting the umbrella topic of climate protection and social equity. It let participants formulate and vote on the question under the umbrella topic, deciding on the scale of the model and setting the subsequent time frame according to their availability. This resulted in the question formulated: “How can we uncouple ecological modernisation and economic gentrification?”. Participants decided it would be beneficial to model this topic on two scales, the entire city scale and the neighbourhood scale (Fig. 4). This led the project team to the change the process and methodology supporting the building of two models: a system dynamics model[55] for the entire city and an agent-based model[56] for the neighbourhood scale.

[55] System Dynamics is an analysis tool that describes a system in terms of its structure and function that generate system behaviour. System Dynamics modelling is most useful for understanding the behaviour of trends over time. (Exter and Specht, 2003).

[56] Agent-based models are computational models that are able to express the dynamics of complex adaptive systems, including the behaviour and interactions of agents within the simulated time and space of a virtual environment. A distinct feature of ABMs is the capacity for linking micro-, meso-, and macro-level factors, shedding light on macro-phenomena emerging from micro-level behaviors and meso-level network interactions. (Shults and Wildman, 2020)

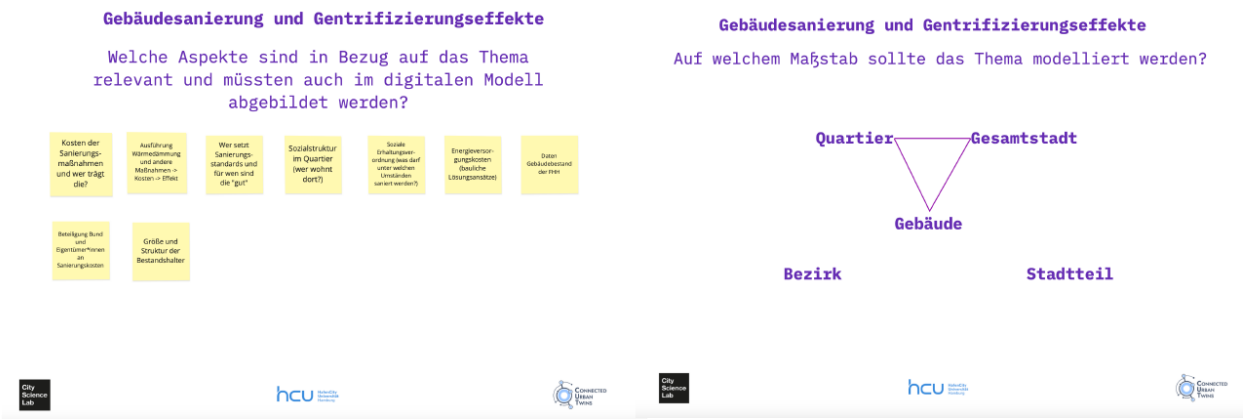

Figure 4: Screenshots from the first modelling exercise (in German). Left: Participants posted relevant aspects of the selected case study (Economic Gentrification vs Ecological Modernisation) on sticky notes. Right: Participants decided to examine the city-scale and the neighborhood-scale, and relate them to the building scale.

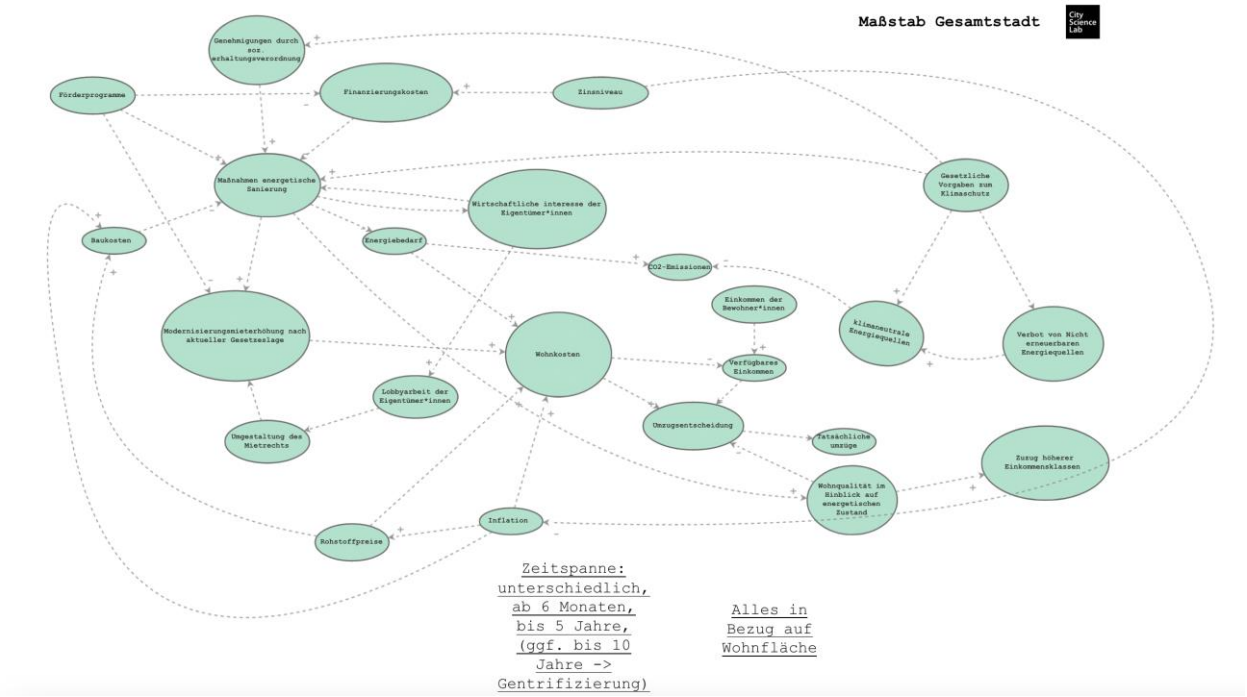

Figure 5: Screenshot from the second workshop (in German): A system dynamics model of the city scale, in which relevant aspects within the case study were mapped and put in relation to each other. For instance, economic modernisation was put in relation to funding programmes, financing costs and permission requirements. Gentrification was translated into the decision to relocate, which was put in relation to disposable income, and living costs.

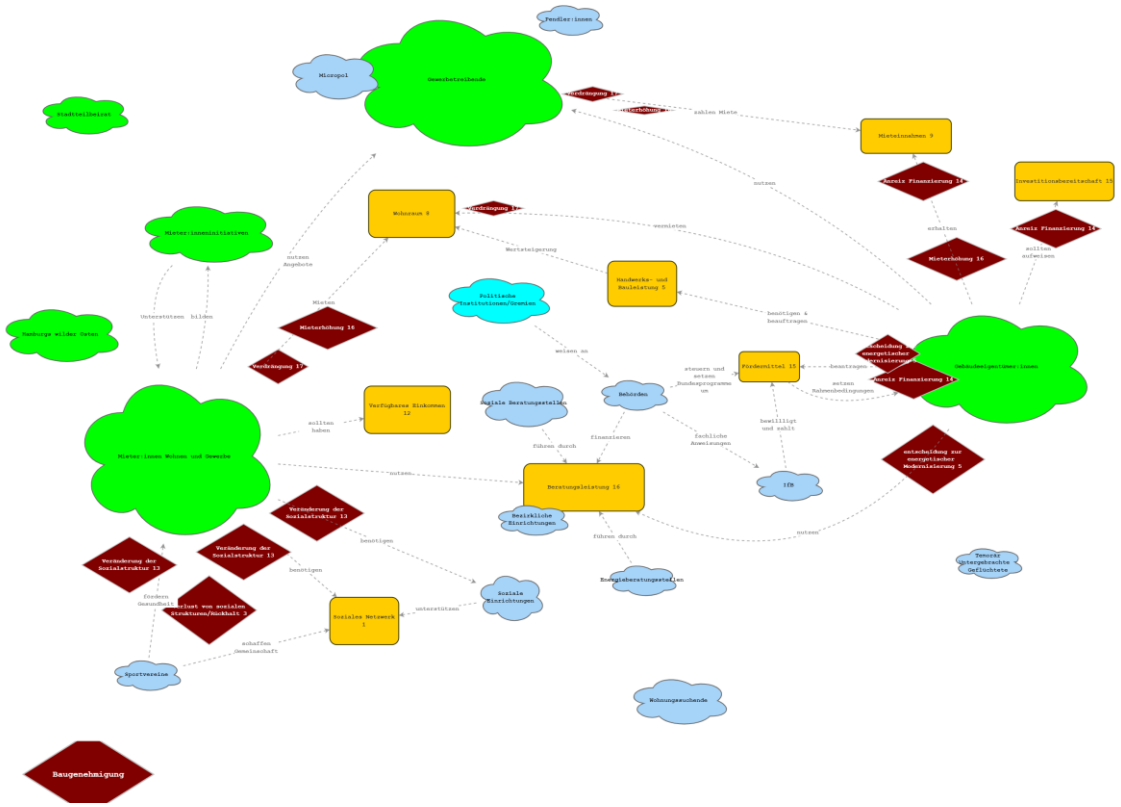

Figure 6: Screenshot from the third modelling workshop: A map was created showing the interaction of direct actors (large cloud) and indirect actors (small cloud), resources (rectangle), and dynamics (diamond). Participants identified tenants, proprietors, and local business owners as main actors. Main resources were the willingness to invest, counseling offers, funding, and disposable income. Main dynamics were push out, rent increase, financing incentives, change of social structure.

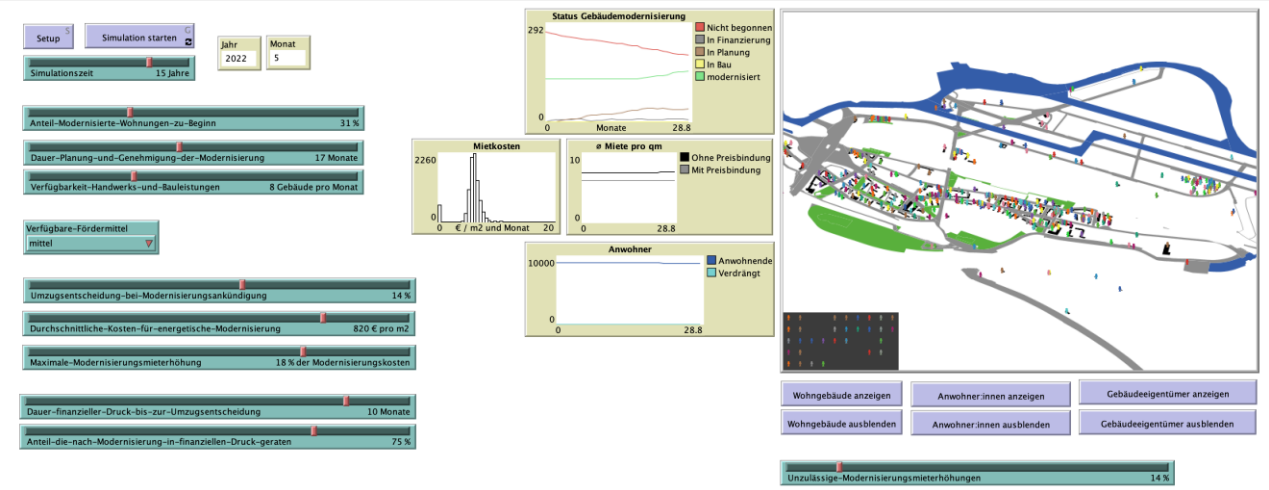

Figure 7: Screenshot from the resulting ABM model, showing interconnections of ecological modernisation and economic gentrification on a meso level for the selected neighbourhood. This model was used in the fourth workshop for testing scenarios.

The **second workshop** then aimed at building the system dynamics model, making use of existing group modelling frameworks (Voinov and Bousquet, 2010; Exter and Specht, 2003; Barreteau, 2003). The half-day workshop was facilitated by a project member of the CUT team, and ideas were mapped using a digital multi touch table and the web based modelling tool *Insight maker*[57]. Participants were asked to name all important aspects of the topics of ecological modernisation and economical gentrification, which included defining these concepts. In a second step, the aspects were put in relation to each other, the third step was operationalising them (Fig. 5). In a second phase, potential neighbourhoods were jointly selected with the stakeholders, based on development areas and areas in the social preservation ordinance.

The **third workshop** focused on the selected neighbourhood, aiming at jointly defining the relevant aspects for the agent-based model by applying an adapted ARDI methodology[58]. In this full-day workshop participants jointly discussed relevant actors, defined the resources those actors were managing, included drivers of change as dynamics in the field, and mapped the interactions (Fig. 6). After this workshop, the project team translated the workshop results into an ABM model using the tool Netlogo[59].

The workshop results were presented in the **fourth workshop**.[60] In this half-day session, the two models were discussed in terms of what concepts were missing from them. The participants were then invited to formulate scenarios that could be tested with the twin models (Fig. 7). In testing the scenarios, discussion arose over concepts and policies. In the final reflection, questions were answered regarding the applicability of the model in work and policy contexts.

[57] https://insightmaker.com/

[58] ARDI (Actors, Resources, Dynamics, and Interactions) is a co-construction method for participatory modelling, usually used in natural resources management. In participatory workshops, various stakeholders co-construct a “conceptual model” of the functioning of a context or territory, according to an overarching, negotiated development question. This sharing of representations is done by means of a series of workshops during which Actors, Resources, Dynamics, and Interactions constituting the profile of the territory are identified and clarified. (Etienne *et al*., 2011)

[59] https://ccl.northwestern.edu/netlogo/

[60] Both models have not yet been published, but the data can be downloaded.
The System Dynamics model data can be downloaded here: https://cloud.hcu-hamburg.de/nextcloud/s/YoP2zg3RsgMKyrf
The ABM model data can be downloaded here: https://cloud.hcu-hamburg.de/nextcloud/s/a5PfsxBXrEWJzCJ

2.4.2 Data Collection and Analysis

This research follows an explorative research design, oscillating between ethnographically-inspired field work and theory adoption (Brüsemeister, 2008). Data collection was conducted during the four above mentioned workshops, but extended over the whole preparation phase, starting around late summer in 2022. Data was gathered in team meetings, both online and offline, during informal interviews with participants, expert interviews, in workshop settings and in reflection conversations. The material was gathered using participatory observation, informal interviewing and document analysis, and consisted of observation notes, field diary notes, interview transcripts, meeting notes, photographs, audio recordings, emails and other artifacts of communications such as powerpoint presentations, as well as the workshop results documentation. The material was coded in MaxQDa using open codes (von Oertzen, 2006). Of these codes, clusters of relevant aspects were formed in relation to the research question and the four dimensions of co-creative twinning:

(1) Twinners: This includes codes on stakeholders involved in the co-creative twinning process, both internal and external to the CUT project. Analysis focused on the conditions for and access to participation. The codes included subgroups (1.1) Building Community, (1.2) Performing Expertise, (1.3) Finding and Making Time.

(2) Practices: This category includes codes showing the practices of collaboration that emerge when citizens actively engage in design activities. This category includes codes of the subgroups (2.1) Filling Gaps, (2.2) Making explicit, (2.3) Quantifying Uncountables.

(3) Agency: The third category encompasses findings on moments when twinners were able to engage transformatively with the structure or process, shaping the process according to their expression of needs and wishes and actively contributing to the design and implementation of the twin. This includes subgroups (3.1) Switching and Staying in Perspective, (3.2) Appropriating the process, (3.3) Co-owning the Product.

(4) In the fourth category, the focus is on moments that highlight the reflexivity of the process. This entails responsiveness to emergence, openness about uncertainties, and attending to exclusions and inequalities of the system of participation. The code subgroups here are (4.1) Transparency and Trust, (4.2) Designing for (Dis-)Order, (4.3) Open-Endedness.

The results will be presented in concise paragraphs referring to the data and related documents. An interpretation and discussion of the results will be provided in the subsequent chapter.

3 Data and Results

3.1 Twinners

3.1.1 Building (and Making Use of) Community

It is important to highlight the relevance of **existing personal networks**, as they played a major role in participant recruitment. Cold-call email acquisition had a lower success rate than recruiting participants through personal networks. One stakeholder's agreement to participate was based solely on a strong existing relationship with one of the researchers:

> I didn't know what I was doing here, but because I've known (…) for ages, I came. When he asks me to come, I come. (WS3/1, Pos. 333[61])

Existing relationships came into play during the workshops. Participants who knew each other previously used the time together to **catch up on work** amidst their busy calendars. During the online workshop, one participant wrote to another in the chat about a work-related topic, and addressed her during the introduction round:

„Please check the chat, if I can't reach you otherwise.“ (WS1/1, Pos. 19)

Some participants were co-workers who aimed to **coordinate their inputs** and reach agreements on topics before engaging with the group (WS2/1, Pos. 61-67 & 294; WS4/1, Pos. 66-67).

New relations were also formed during the process. Two participants working in the same field but previously unknown to each other developed familiarity and even **formed alliances** to advocate for their agendas (WS3/1, Pos. 315). Participants **socialised** during breaks and workshops, further strengthening community bonds. Practices of **storytelling** and **humour** were employed by participants and facilitators alike. Humour helped overcome frustration in difficult situations, and it also facilitated understanding across political disagreements. As participants were asked to map the process of rental increase in the third workshop, the representative of landowners and the counselors for tenant rights had opposing views which could have led to conflict bus was dissolved by humor (WS3/1, Pos. 322-327). Storytelling was employed to share knowledge on complex definitions. In one example, children had been identified as specifically vulnerable through displacement induced by neighbourhood relocations, and the cushioning effects of social networks have been emphasised through storytelling (WS3/1, Pos. 226-229).

[61] Subsequently, the quotations will disclose the source data by referencing workshop number, document number and position in the document in the following style: WS3/1, Pos. 333 = workshop 3 / document 1, Position 333).

3.1.2 Performing Expertise

Stakeholder participation fluctuated throughout the process, with varying numbers present in each workshop. The core workshop group consisted of members from urban planning authorities, tenant associations, a resident, and a representative from property owners. While the main roles were represented, participants also **included perspectives from non-present roles**. Through their collaboration with actors in their field, they were aware of the requirements important to these actors. For example, a property owner contributed knowledge on building funding programs by federal investment banks (WS3/1, Pos. 358), and a member of a neighbourhood association provided insights on elder tenants (WS1/1, Pos. 109).

Participants **emphasised their experience** in the field, either in terms of years of service („After years of dealing with the subject matter (…)“, WS1/1, Pos. 89) or involvement in lighthouse projects that had received considerable publicity (WS1/1, Pos. 28). This performance of expertise became apparent in the starting phase of the project during introductory moments and more noticeably during controversial discussions (WS3/1, Pos. 364-366; WS4/1, Pos. 60-62).

3.1.3 Finding and making time

Participants' availability and willingness to participate in the workshops were strongly influenced by the time resources they had. Those invited in their professional roles were able to dedicate their working hours and were available on weekdays during office hours. Those invited based on their non-occupational roles had to find time during their leisure hours, often in the evenings. Participants with care responsibilities were more available in the mornings during school hours. Counsellors working with marginalised communities faced time constraints towards the end of the month due to the accumulation of legal actions related to leases ending. Most participants expressed regret over having **limited time** (WS1/1, Pos. 21 & 198). **Coordination of dates** thus became important, and workshop dates were timed according to participant’s availabilities (WS1/1, Pos. 198 & 199). Being pressed for time resulted in participants **leaving the workshops earlier or joining later** (WS1/1, Pos 67 & 188). **Last minute cancellations** resulted in important perspectives not being present in the workshops (WS1/1, Pos. 245).

The **willingness to clear their schedule** was also influenced by how well they understood the experiment and if they saw how they could achieve an impact by participating. One neighbourhood activist from the critical urbanism community declined his participation via email after attending the kickoff workshop, as he did not want to invest his limited time to a project he did not see value in:

I wanted to let you know that I can't (and don't want to, it's always a matter of priorities) afford to take part in the project any longer. (…) I don't really see where fundamental criticism or other approaches could be implemented or even discussed in this modelling project. (…) I don't have the resources for a small-scale technocratic discussion. (WS1/2, p. 1)

If participants understood the experiment well and saw how they could make an impact, or if the topic was relevant to their interests, they were more likely to clear their schedule for the workshops:

I know the next meeting is during my holiday. But if I were to be in Hamburg then, I would actually come to it during my holiday too, because I find it really exciting. (WS3/2, Pos. 18)

3.2 Twinning practices

3.2.1 Filling Gaps

Participants noticed and pointed out missing actors (WS1/1, Pos. 58; WS2/2, Pos. 195; WS3/1, Pos. 257-258). Some actors had not responded to the invitations (WS3/1, Pos. 257-258), had dropped out of the process (WS3/1, Pos. 12) others had cancelled their participation last minute (WS1/1, Pos. 14) or not shown up without further notice (WS3/1, Pos. 18).

However, the present participants made an effort to include those missing perspectives in the workshops. So did the tenant counsellor take on the role of economist (WS2/1, Pos. 195), or provided knowledge on tenant law (WS2/1, Pos. 165-166). And others pointed out the specific situation of elderly tenants (WS 1/1, Pos. 109). In a several instances, gaps in the built model were noticed by several participants at the same time, independently (WS2/1, Pos. 183-184).

3.2.2 Making explicit

Given the abstract practice of building a digital model, unclarity was expressed at times. Throughout the workshop, several practices of making explicit emerged, such as asking each other, explaining concepts, clarifying abstract notions, building coherence, specifying ideas, and reducing or extending complexity:

From the question that was there at the beginning to what we have worked out now, we have somehow made the problem less complex and at the same time it is still complex, but much more understandable. (WS2/2, Pos. 8)

During a simulation exercise in workshop 4, a scenario was selected to test the impact of a new policy capping the percentage of modernisation costs that could be transferred to renters. However, the results showed that the rent continued to rise regardless of the

policy setting. In testing which factor dominated the calculation, participants found that inflation commanded the rent increase more than any other factor. This instigated a discussion on missing factors in the model that could counterbalance inflation. The participants recognised the deceptive nature of the inflation factor and agreed to differentiate it into "pay increase" and "total price increase.“ The model did not only facilitate the testing of policy recommendations, but also made explicit which factors had been deemed of essence, and which had not been included, and the reasons why.

Participants expressed that through the simulation of the models, relevant and irrelevant strategies became apparent:

> And I believe that these models offer the possibility of a much better qualified exchange about individual aspects. (…) I think we can then somehow steer the discussion a little bit, so that we can say, ‚Are we going to talk about nothing here or are we going to tackle the big issues somewhere?‘ I think that could support something like that very well. (WS4/2, Pos. 3)

3.2.3 Quantifying uncountables

In the modelling process, participants faced the challenge of **quantifying abstract concepts** related to the nexus between energetic modernisation and gentrification through rent increase. Some indicators could be easily calculated (rent = net cold rent + utilities), obtained from available data sets (number of residents in selected neighbourhoods), or were fixed numbers that could be taken from statistical or public data (inflation level, average square metre rental price). Others, such as ‚knowledge on tenant law‘, ‚social networks‘, or ‚decision to relocate‘, proved difficult to quantify. To give an example: When discussing the indicators of a social network for the agent-based model, participants named the number of contacts, the level of efficiency of these contacts, the contacts in the right positions of power, the law competence of the contacts, and the number of advice centres (WS3/1, Pos. 253). Participants recognised the importance of including these factors in the model, even if their quantification seemed impossible. It was decided to model these concepts as fluid factors on a scale from low to high, acknowledging their influence on other factors.

3.3 Agency

3.3.1 Switching and staying in perspectives

Participants employed various strategies to address differing perspectives. Those included, but were not limited to, objecting, overruling, finding consensus, agreeing. However, in cases where conflicting perspectives emerged, **negotiation and constructive discussions** took place. For instance: During a mapping exercise, two opposing perspectives were negotiated. The perspectives of the representative of

proprietors, who focused on the profitability of modernisation measures, differed from those of the lawyers advocating and counselling for tenant rights, who focused on the affordability of housing. The group had identified “displacement” as an important process and was attempting to map out the individual process steps. The proprietor differentiated that this process would proceed differently for tenants than for residing proprietors, as tenants would face the result of rent increase, but residing proprietors would face the result of compulsory reconstruction with differing effects. The group decided to map two different processes for each stakeholder group (WS3/1, Pos. 306-313).

In the process, participants mentioned how they gained knowledge from each other (WS2/2, Pos. 3), but even more, that the process is suitable to teach about the complexity of urban planning:

> I found it very exciting to see how what we did in the morning now assembled. Sometimes I had difficulties to combine some things in a logical way. But I believe it is very difficult, because we chose two unbelievably complex questions. (…) And I learned a lot and found it very interesting to bring in all these facets and on the other hand reduce the complexity. (…) You could really sense today that urban planning is immensely complex. (WS3/2, Pos. 10)

3.3.2 Appropriating the process

Participants showed a strong interest in the topic and its potential impact, leading them to allocate time and effort to participate in the workshops. They expressed a **desire for new knowledge** to support their work and recognised the workshops as an **opportunity to connect with others** in their field (WS1/1, Pos. 18, 22 & 26; WS2/2, Pos. 3; WS2/1, Pos. 165-166; WS3/2, Pos. 3). They used the workshops as a platform to exchange information and connect on related projects. Specifically during the pauses, participants gathered around the catering area or in other areas of the room, exchanged on recent events relevant to their work, or connected on projects that needed updating (WS1/1, Pos. 19; WS3/1, Pos. 153).

Additionally, participants used the workshops to achieve their individual goals, putting their topics on the agenda and campaigning for modelling an ideal state. For instance when discussing the questions that should be modelled:

> (The important question is) who uses how much housing in the city. We are always told we need more housing space. What is disregarded there is, that social housing has clear guidelines regarding the number of square metres. But in owner-occupied housing there is no political control of how much space people use. This question would be important to me to depict in the model, because it is a question of justice. (WS1/1, Pos. 134)

3.3.3 Co-owning the product

The high relevance of the topic and the perceived possibility to create an impact can be described as one of the most motivating factors for participation. Participants mentioned their interest during the preliminary interviews as well as in the workshops (Documents 0/1, 0/2, 0/3, 0/4 and WS1/1). They captured the modelling states, requested documentation and screenshots for reporting purposes (WS1/1, WS2/1).

Participants **developed a sense of ownership** and took pride in the final product. Upon reflecting on the co-creative work, one participant said:

> I found it super constructive. I came here with relatively few expectations or few concrete ideas, and I find it amazing that we have now, let's say, got a model together. And it's interesting what you were able to contribute to it and what has become of it and what I was able to take away from all of you and what I found, yes, what I learned. (WS2/2, Pos. 3)

Two explicit moments of co-ownership became apparent throughout the end of the process. A tenant-lawyer reported about a federal assembly of their tenant alliance where they would like to present the tool in order to support their lobby work (WS4/2, Pos.18-22). Another participant employed by the ministry of housing and urban development showed interest in presenting the results to their partnering ministries in other German states (WS4/3, Pos. 13).

3.4 Reflexivity

3.4.1 Transparency & Trust

Building a digital model of a social process co-creatively is in itself quiet a complex and abstract undertaking. Turnout for participation might have been influenced by this, however the data to proof this is lacking as participants did not always share their reasons for not joining the experiment. Those participants who did take part, expressed how confusion turned into understanding, showing they held a **tolerance for disorientation** during the process: „I felt like the others – before I had a knot in my head – what do they want? – this has dissolved. I find it so great that I want to continue to participate.“ (WS 1/1, Pos 218

Holding the space for disorientation and guiding participants to the end helped to create trust in the process. This was aided by the transparent process structure:

> I did not only understand the question, I also won trust. In the way that; the clutter will dissolve eventually and I will have the insight. I found that incredibly terrific. (WS4/2, Pos. 22)

3.4.2 Designing for (dis)order

Following Voinov and Bousquet (2010), the process steps and a minimal structure were defined, which could be shuffled and allocated as needed. The overall time frame for the process was set from February to April, with three stages: Kickoff, Modelling, and Conclusion. The workshops took place in the showroom of the CityScienceLab in Hamburg, and the overarching topic was climate protection and social justice. Detailed decisions were made collectively, including continuously reformulating the research question and setting the scale, which impacted the process, such as transitioning from one model to two models and conducting separate modelling workshops.

For the researchers, the openness of the process was important to allow for emerging co-ownership. Various strategies were employed to provide stability within the open process. Before each meeting, a comprehensive information document was shared, outlining the process steps, previous workshop results, and the goal of the upcoming meeting. Meetings began with reading the agenda and introducing everyone, followed by presenting outputs from previous workshops and ending with a reflection round. Strict time management was implemented during the workshops to avoid exceeding the allocated time. Ample breaks were incorporated into the program for recovery and socialising, and catering was provided. Each workshop was followed by a summary of the results and an outlook on the next steps.

Participants admitted feeling confused at times and uncertain about the project's outcome, but they also appreciated the systematic agenda and strict timing as that provided a sufficient framework for productive collaboration (WS2/2, 3/2). By offering a stable framework, trust was established, giving stakeholders the security for experiencing confusion.

> It is a very complex topic and I had my problems imagining what would be the result. But the system you used was very helpful in structuring the steps and the result at the end. Even though it still looks very complicated, it has brought order to the whole thing. In a comprehensible way, where we could incorporate our, let's say, our knowledge. So the idea to make the development of such models more transparent, and people who are involved with it on a daily basis can give their input, I think that works well within this framework. (WS3/2, Pos. 11)

3.4.3 Open-Endedness

An element of Designing for Disorder was to design the process in such a way that it was open to changes. This way, participants had the agency to make alterations in the process, the timings, and the result. The process had to have this openness in order to allow for different models to be built in case participants were not agreeing with each

other. Only this openness allowed for a diversity of representation of reality. However, it also involved a higher level of organisation and trust.

When the co-creative process started, there was still uncertainty about the scale and number of models to be built, and thus, about the timeline of workshops. Without a pre-formulated vision of the resulting model, participants did not have a goal towards which to work and had to rely on the process and results emerging from it. While this was at times challenging, it allowed for constant input, influence and decision-making by participants who shaped the process and results.

> It is a very complex topic and I always had problems imagining what the result will be. But I find this system that you use, in any case, I think it structures it very well. These steps and what comes out in the end. Even if it still looks very complicated, it has brought order to the whole thing. In a comprehensible way, where we could incorporate our, let's say, our knowledge. So the idea is to make the development of such models more transparent and to allow people who are involved in it on a daily basis to give their input. I think that works well within this framework. (WS3/2, Pos. 11)

3.5 Analysis

The results outline how the four dimensions of co-creation are manifested in the twinning case study. They indicate that a careful design of co-creative twinning workshops and consideration in selecting stakeholders is required to open up space for communication and acting together, allowing for the emergence of trust, transparency and agency. The analysis of the case study highlights 6 lessons learned for co-creative twinning, which are discussed below indicating challenges and potentials that play a role in understanding and designing for co-creative twinning.

The importance of stakeholder selection and community: The process highlighted the significance of carefully selecting stakeholders based on their expertise, in order to include a diversity of perspectives. Participants socialised during pauses and workshops, forming alliances and coordinating their inputs. Trust and familiarity between stakeholders played a role in their decision to participate. Existing networks, personal and professional relations that extend the project runtime can be used to recruit diverse perspectives to the process. Designing workshops in a way that allows for socializing gives participants the possibility to catch up on projects and extend their personal and professional networks, acting as a motivating factor.

The influence of roles and motivation on participation: The availability of time resources significantly influenced participants' ability to engage in the co-creative process. Time resources depended heavily on the role participants had during the workshops. Participants' availability and willingness to participate in the workshops were strongly influenced by their motivation and role in the process. Allowing flexibility in

setting the timeframe was crucial, but it also required higher organisational effort and introduced uncertainties in the project plan. Understanding the impact of time availability on participation can help in designing inclusive processes that accommodate different stakeholders' schedules.

Setting a minimum framework to allow for (dis)order: This is a challenge both to practitioners as well as involved stakeholders, however it is a prerequisite to allowing diverse perspectives to be included, to appropriate process and product. In defining a minimum framework, co-creative twinning practitioners can create boundaries that help foster trust in the twinning group. In letting other aspects undecided, practitioners can support negotiation and collective decision-making.

Co-creative modeling helps making latent knowledge explicit: Participants acknowledged that the models facilitated more qualified exchanges and helped focus the policy discussions on key issues. The modelling process allowed for a better understanding of the complexity of the urban context and the concept of gentrification. Through practices of inquiring, challenging, explaining, objecting, advocating and building coherences, participants engaged in reifying notions of the urban. The model and the modelling process supported making implicit knowledge tangible in exposing hidden assumptions. This observation was also validated by the participants who emphasised frequently how the process helped grasp the complexity of the urban and of the selected concept of gentrification.

Coping with conflict and differing perspectives: Participants employed various coping strategies when faced with conflict and differing perspectives. In cases where conflicting perspectives emerged, negotiation and constructive discussions took place. The model facilitated this negotiation, reconfigured knowledge and perspectives, and broadened the design space. Understanding these strategies can help in designing future co-creative processes that foster constructive discussions and negotiation of different viewpoints.

Developing co-ownership of the model: Participants developed a sense of ownership and took pride in the final product. By actively participating in the modelling process, they gained a deeper understanding of the tool and its underlying assumptions. Stakeholders appropriated the process for their own goals and expressed ownership of the product, taking it into other contexts. This highlights the potential for co-creative processes to generate value beyond the immediate project outcomes.

3.6 Conclusion

The research shows that complex models for digital urban twins can indeed be modelled co-creatively. The four dimensions of co-creative twinning have been helpful in analysing the dimensions of co-creation, and the research describes emerging practices and requirements for stakeholder involvement as well as potentials of co-creative twinning. It also reflects on the challenges of employing these methodologies and pitfalls to be mindful of. Further research could focus on the concrete outcomes of these processes on digital urban twins, both in terms of the structure and quality of the resulting models, as well as the quality of the source code. How does data of socio-ecological topics translate to the models, and how is complexity visualised and debated? The author looks forward to expanding on these topics, deriving a framework for analysis and defining design principles for co-creative twinning, and encourages other researchers to test the framework in different twinning settings.

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