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PaSyMo: Gamifying Communicative Urban Planning With Participatory Systems Modeling

Timo Szczepanska [1,2], Max Priebe [2,3], Leonard Higi [2,4], and Tobias Schröder [2]

[1] The Norwegian College of Fishery Science, UiT The Arctic University of Norway, Norway
[2] Institute for Applied Research Urban Futures, University of Applied Sciences Potsdam, Germany
[3] Fraunhofer Institute for Systems and Innovation Research ISI, Germany
[4] Institute of Urban Planning, Brandenburg University of Technology Cottbus-Senftenberg, Germany

Correspondence: Timo Szczepanska (timo.szczepanska@uit.no)

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Abstract

Urban planning increasingly requires navigating complex socio-spatial dynamics and uncertainties, particularly when addressing social challenges where stakeholders hold diverse perspectives and knowledge. This article introduces PaSyMo (Participatory Systems Modeling), a gamified communication support system designed to assist urban planners in communicative and deliberative planning. PaSyMo integrates three conceptual pillars that guided its design: stakeholder engagement, participatory agent-based modeling (ABM), and visualization on tangible interfaces. The system combines a simulation environment grounded in geodata and ABM with discursive elements from scenario workshops and role-playing games, bridging digital and non-digital formats. PaSyMo contributes to the growing field of GAM research (Games and Agent-based Modeling; Szczepanska et al., 2022) by providing a framework that explores the integration of gaming mechanics with urban simulation tools, highlighting their potential to support sustainable urban planning. The approach draws from participatory modeling (Sterling et al., 2019; Voinov & Bousquet, 2010) while leveraging state-of-the-art geospatial simulation and interactive interfaces to facilitate communication and co-production of knowledge among diverse stakeholders. Exploratory findings suggest that combining gaming experience with geospatial data visualization and ABM offers a promising approach to communicate the potential implications and trade-offs of urban planning initiatives. This integration enhances stakeholder engagement, promotes shared understanding, and supports consensus building. By making urban planning processes more interactive, PaSyMo can extend the impact of planning research beyond academic settings. Preliminary insights indicate that PaSyMo can enhance stakeholder understanding, knowledge integration, consensus-building, and proactive planning, especially in contexts of decision-making in complex and uncertain situations; however, these findings need to be substantiated in future studies.

Keywords
agent-based modeling; games; participatory simulation; spatial simulation; urban planning

1. Introduction

Planning and managing urban systems involves high degrees of uncertainty, especially when planners confront social problems, where conventional approaches that aim for single-point solutions often fail to deliver the intended outcomes. Shortcomings of traditional planning solutions can be attributed to a lack of understanding of the underlying complex interdependencies of various interconnected social, ecological, and technological drivers. These challenges are often framed against the backdrop of "wicked problems" that are difficult to define, have multiple possible solutions, and cannot be easily categorized (Rittel & Webber, 1973). Even agreeing on what the problem actually is can become a major challenge, sparking conflicts among groups with differing and sometimes opposing interests (Head, 2022). Under the lens of the wicked problem, problem-solving strategies that do not consider multiple stakeholder viewpoints fail to yield sustainable planning strategies, as they may lead to an imbalanced representation of one interest group at the cost of creating problems for another one.

The communicative turn in planning accordingly transformed the discourse in planning theory at the end of the twentieth century. Rather than claiming to find the "correct" solution, planners use communication, consultation, or deliberation to grasp an understanding of the distinction between observed and desired conditions, investigate different ways of identifying problems in the complex causal networks, and stimulate the exchange between laypersons' experience and planners' expertise (Healey, 1992; Innes, 1995). Planning as a collaborative, interactive, and communicative approach can generate the coordination and innovation that is necessary to respond to complex problems (Innes & Booher, 2010). Batty (2013) echoes these communicative planning ideals, arguing that science and technology should inform dialogue rather than generate definitive answers.

With this aim in mind, we present *PaSyMo* (Participatory Systems Modeling), a gamified simulation and data visualization environment. Its goal is to support communicative planning by providing a mobile simulation lab (MSL) that provides a virtual laboratory for users to interact directly with a simulation model of a relevant urban system. In doing so, stakeholders in planning problems can playtest different interventions and examine their effects on a target system, i.e., aspects of the real-world system that are studied to gain knowledge (Elliott-Graves, 2020), by simulating and visualizing a range of "what-if" scenarios.

We also report on exploratory tests of this environment in a series of participatory workshops with stakeholders on a few urban planning cases in the state of Brandenburg, Germany, between 2017 and 2019. These situated test cases are instructive for the technical development of a frugal and context-sensitive approach and provide some first insights as to how gamified simulation and data visualization can support communicative planning. A future research agenda based on these preliminary observations will allow us to study the impact of urban simulations on communicative planning efforts.

The article is structured as follows. Section 2 describes relevant conceptual background and prior research guiding the development of PaSyMo. Section 3 describes the PaSyMo MSL, considering hardware and software components but also possible workflows in the context of communicative planning. Section 4 then presents three examples of how PaSyMo was implemented in real-life urban settings, illustrating its intended use. Finally, we discuss limitations and avenues for future systematic research to evaluate the usefulness of the approach.

2. Conceptual Background

Computational tools have supported urban planners in their work since the 1970s. Over time, advances in technology have not only fueled social innovation in spatial planning (Christmann et al., 2018) but also provided effective means for the communicative turn in planning (Diller et al., 2018; Healey, 1992). Existing studies provide a broad range of examples for how tools can be used to foster participants' engagement in urban planning contexts, such as participatory GIS (Dunn, 2007); interactive Web-GIS (Marras et al., 2018; Panagiotopoulou et al., 2020); participatory apps (Desouza & Bhagwatwar, 2012; Ertiö, 2015); e-participation (Aichholzer & Strauß, 2016); online deliberation via platforms (Münster et al., 2017); neighborhood labs (Kontokosta, 2016); or data visualization (Hemmersam et al., 2015). Beyond single approaches, recent work in the field of planning support science has increasingly focused on context-sensitivity and governance to better tackle the implementation gap of planning support systems (Geertman & Stillwell, 2020; Jiang et al., 2020). Our contribution lies in addressing the implementation gap in developing a prototype of a support system that can be tested and refined in a relevant environment, such as participatory workshops in urban planning contexts. PaSyMo integrates three conceptual pillars that guided its design: *stakeholder engagement*, *agent-based modeling* (ABM), and *visualization on tangible interfaces* (Figure 1).

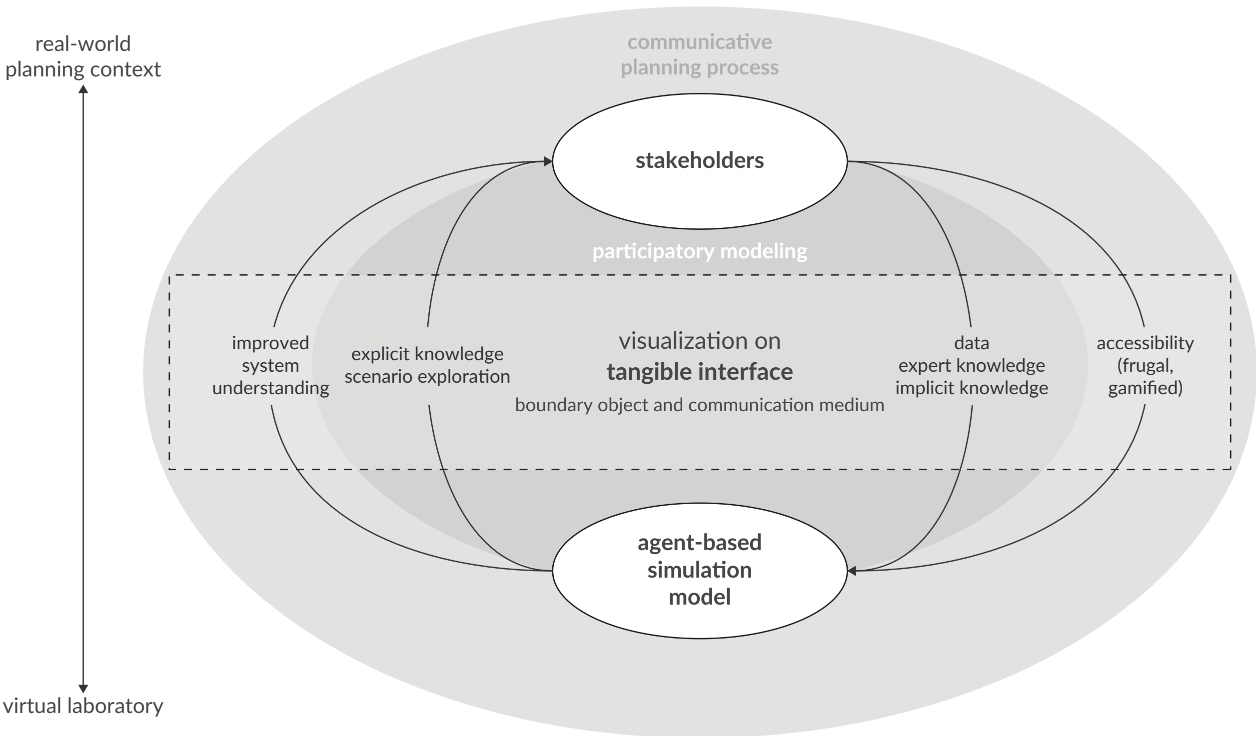

Figure 1. Conceptual design of the MSL.

The communicative turn emphasizes collaborative decision making and *stakeholder engagement* (Healey, 1992; Innes, 1995). Classic works in urban planning, such as Arnstein's (1969) typology for participatory planning, illustrate how policymakers have gradually refrained from claiming objective and definitive solutions to social problems (Diller et al., 2018). Unlike conventional expert-driven approaches, which centralize knowledge and decision-making, participatory planning redistributes power, placing stakeholders at the heart of the process (Cornwall & Jewkes, 1995).

Situated at the intersection between early planning phases (engaged with exploring, scoping, and visioning) and formal planning activities leading to actual zoning, PaSyMo lends itself to public engagement workshops as a structured approach that aims to support stakeholder exchange, rendering planners' domain expertise as well as residents' tacit and local knowledge visible. It provides space for visioning, in which participants' implicit assumptions of the realities and workings behind a specific urban issue at stake are made explicit and represented in a conceptual model that serves the multi-stakeholder focus group as a "boundary object" (Star & Griesemer, 1989). In the case of PaSyMo, the boundary object constitutes a communicative space and interactive visualization that helps to generate shared meaning, prompts participants to make assumptions explicit, while at the same time sustaining interpretive flexibility (Figure 1).

Participants are not passive recipients of expert advice; they actively contribute to defining problems, setting objectives, and designing potential interventions. Their involvement is a crucial element as it counters the danger of creating a system of corporatism, technocracy, and surveillance that is often raised as a concern in smart city discourse (Greenfield, 2013; Hollands, 2015; Vanolo, 2016). PaSyMo follows this principle by enabling stakeholders in co-creating knowledge throughout a planning process. They might define relevant scenarios and contribute both explicit and tacit knowledge to inform the simulation models, exploring what-if scenarios to co-create insights collaboratively. This approach aims to create meaningful dialogue, integrate diverse perspectives, and enhance the relevance and legitimacy of planning interventions.

Recognizing the complex nature of cities has led to the development of methodological approaches that aim for better insight into their underlying dynamics (Batty, 2013; Crooks et al., 2021). ABM is a powerful method for studying complex adaptive systems, capturing dynamic behaviors through the interactions of individual components. In ABMs, the components of a system are instantiated as software agents, each characterized by multiple attributes and guided by formal decision-making rules (Miller & Page, 2007). Simulation outcomes can therefore be traced back to individual agent characteristics and behaviors, making ABMs particularly suitable for systematically exploring counterfactual development scenarios and understanding emergent system-level phenomena (Heppenstall et al., 2012). ABMs also contribute to theory development by providing an experimental platform to investigate social processes from the individual to the societal level (Epstein, 2008; Gilbert & Troitzsch, 2005). Within computational social science, ABM has increasingly been combined with participatory and gaming approaches to support collaborative learning and engagement. Participatory ABMs integrate methods ranging from role-playing games to fuzzy cognitive mapping, providing technology-supported avenues for public involvement in planning and decision-making (Voinov et al., 2018). These models have a long-standing application in disciplines concerned with emergent phenomena in complex systems, including environmental sciences (Barreteau et al., 2013; Carmona et al., 2013; Gray et al., 2017), landscape planning (Becu et al., 2017; Van Berkel & Verburg, 2012), and organizational studies (Andersen et al., 2007).

In PaSyMo, participatory ABM serves as the computational backbone for the simulation environment. By integrating ABM with stakeholder participation, the system allows users to define scenarios, contribute both explicit and tacit knowledge, and explore "what-if" interventions collaboratively. This combination of ABM and participatory design ensures that the simulations reflect real-world dynamics, support collaborative learning, and provide an accessible platform for co-creating knowledge in complex urban planning contexts.

While ABMs are conceptually powerful, they are often difficult for laypersons to interpret and challenging to apply in collaborative group settings. Participatory modeling approaches address this limitation by combining ABMs with *tangible interfaces*, enabling stakeholders to engage directly with models in an intuitive, interactive manner (Shaer & Hornecker, 2010). In recent years, technological advancements such as virtual and/or augmented reality (VR/AR), touch interfaces, and other innovative input devices have contributed to more immersive user experiences that blur the lines between the simulated world and reality (Marto & Gonçalves, 2022). Such tangible interfaces have found various applications in communicative planning, education, and science communication efforts, with modes of user interaction within physical and digital realities through direct manipulation, gesture recognition, or real-time scanning of printed code snippets (Hermansdorfer et al., 2020). In spatial setups, the tangible table is a well-suited arrangement to simplify the complexity of a design process by combining intuitive user input through physical interfaces with simulation and visualization (Petrasova et al., 2018) on 3D printed maps, sandboxes, or laser cut maps (Salim, 2014).

Tangible interfaces for ABMs bridge the physical world of participants with the virtual dynamics of the model, allowing users to manipulate variables, explore interventions, and visualize and debate outcomes. Such approaches have been employed in diverse contexts, including tabletop simulations of urban management practices for mobility and air quality interactions (Minh Duc et al., 2020) or as testbeds for alternative physical interfaces such as LEGO bricks in the CityScope platform (Alonso et al., 2018; Noyman et al., 2017). In PaSyMo, we employ a multitouch table to combine the flexibility of virtual objects with intuitive, hands-on interaction. Virtual objects can be easily adapted to different scenarios, reducing dependency on physical artifacts designed for specific use cases. This setup allows participants to collaboratively manipulate and explore simulation models, supporting both engagement and co-creation of knowledge.

The conceptual design of PaSyMo situates it within the domain of *geogames*. Ahlqvist and colleagues defined geogames as digital or hybrid games that use real-world spatial data and GIS to mediate interaction with geographic environments, emphasizing authentic geography (Ahlqvist et al., 2012; Ahlqvist & Schlieder, 2018). Recent research on geogames in the domain of urban design and planning explores how interactive play, geospatial data, and simulation can foster civic participation and engagement (Poplin, 2012, 2025). PaSyMo contributes to this area of research by embedding an ABM directly within the game setup. GAM-Research (Games and Agent-based Models) has been proposed as a methodological framework for systematically combining gaming approaches with ABM to study complex social phenomena (Szczepanska et al., 2022). In GAM research, Games provide accessible and engaging environments for eliciting human decision-making, while ABMs contribute formal, dynamic representations of system behaviors. GAM-Research distinguishes six design types, which differ according to the sequencing and integration between the game and the model. PaSyMo corresponds to a GAM design type 5, in which the ABM is embedded directly into the game environment (Szczepanska, 2023). Framing PaSyMo as a GAM design type

5 emphasizes its dual function: as an analytical instrument for studying urban processes and as a participatory medium for collaborative sense-making. By combining ABM, tangible interaction, and real-world geodata, PaSyMo presents a framework to operationalize geogames for deliberative, participatory settings for communicative planning. Its geodata-driven design enables stakeholders to experience and explore case-specific what-if scenarios, test potential interventions, and collaboratively interpret their impacts.

3. The PaSyMo MSL

The MSL is the physical implementation of PaSyMo. Its design is guided by two fundamental principles. First, the MSL introduces state-of-the-art spatial simulation and visualization technologies into participatory planning processes. Second, it follows a frugal approach, requiring minimal financial investment and technical expertise. This frugal approach acknowledges the financial and expertise constraints faced by smaller municipalities, which are often excluded from costly technological innovations. Frugal innovation seeks to “do more with less” (Bhatti, 2012), a principle that extends to both the hardware and software components of the MSL. All hardware components are consumer electronics, while the software relies solely on open-source tools and publicly available data. Additionally, the system is flexible and reusable, featuring adaptable simulation models and a mobile setup that can be deployed in diverse planning contexts.

3.1. Hardware and Software Components

The *physical setup* of the MSL (Figure 2) consists of a server, an ultra-short-throw projector, an infrared touch sensor, a flat-screen display, and a foldable projection table with integrated mounts for all components. Each element was chosen to support the compact design of the MSL while remaining powerful enough to operate under varying lighting conditions and handle simulations of different levels of complexity. For mobility, the

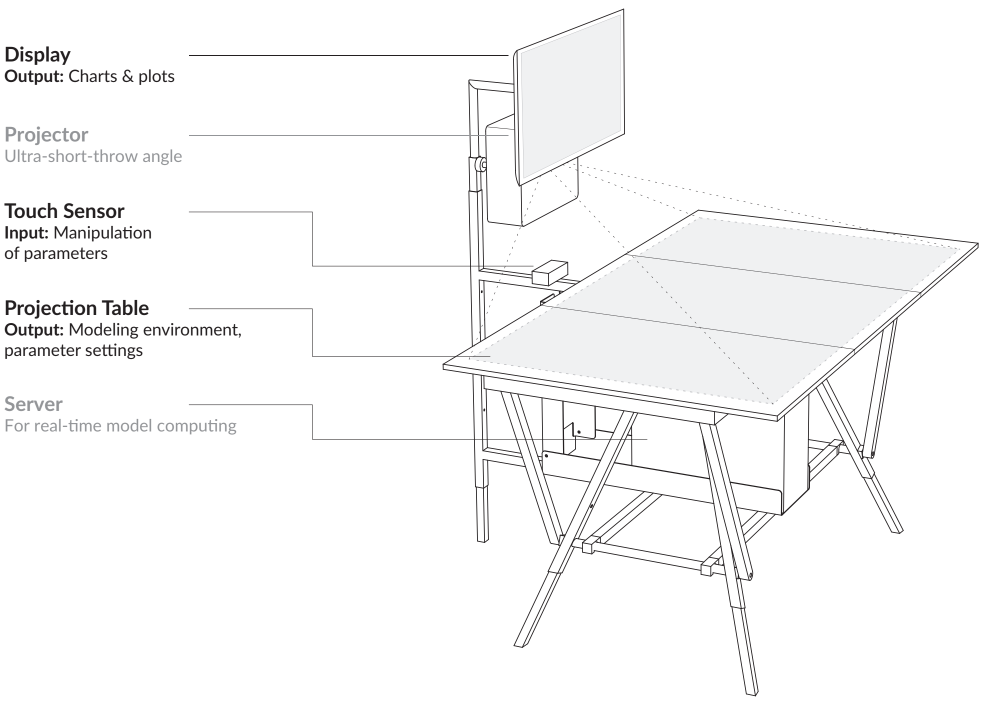

Figure 2. Technical illustration of the physical setup of the MSL.

setup is complemented by a custom-made e-bike trailer, which allows compact stowage of all components and easy transportation.

In functional terms, the PaSyMo MSL combines a simulation model, data visualization for information aggregation, and tangible interfaces to support intuitive human–computer interaction. During workshops, the spatial modeling environment is projected directly onto the table surface and controlled via finger touch. Complementary information, such as data or graphs linked to selected objects on the table, is displayed on the flat screen, providing participants with both interactive and detailed views of the simulation.

The *simulation component* of the MSL is designed to create spatially explicit, interactive models that stakeholders can easily connect to by encountering virtual representations of their physical surroundings. This spatial grounding supports engagement and fosters intuitive understanding of complex dynamics in urban systems.

At its core is the GAMA Platform (GIS Agent-based Model Architecture; Taillandier, Gaudou, et al., 2019). GAMA provides a comprehensive modeling language, a well-structured graphical user interface (GUI), and flexible options for user–model interaction, which enable experts to develop spatial simulations with limited training (Taillandier, Grignard, et al., 2019). Its strong integration with GIS data allows for responsive visualizations. Agents can be generated and informed directly from geospatial data, including objects such as roads, buildings, land use, elevation, waterways, and administrative borders, as well as continuous fields such as population density or environmental indicators.

Interaction with the simulation is supported through multiple channels (Table 1). The projection table allows direct manipulation via finger touch, enabling participants to take workshop role-specific actions like adding or removing objects, modifying parameters, and changing spatial characteristics in real time. Predefined functions can also be triggered via buttons, sliders, or drop-down menus, while pointer movements in the visualization can influence agents and objects dynamically. For instance, users can block or open roads, alter

Table 1. Modes of interaction with the MSL.

Mode of Interaction	Interface	Time	Purpose
Model environment interaction	Touch on projected simulation environment	During simulation run	Take workshop role-specific actions and influence or setup model objects or agents (e.g., insert a new building)
Parameter manipulation	Buttons/sliders/drop-down menus of integrated modeling environment's GUI	Before simulation setup or during simulation run	Take workshop role-specific actions (e.g., insert a new building), trigger predefined functions
Digital surveys	PaSyMo survey app for geographically explicit statements or Google Forms	Before simulation setup	Inform simulation parameters (e.g., set of agents)
Indirect interaction via workshop setting	Role play, graphical tracking of discussions and model runs, e.g., on posters	During simulation workshop	Embed simulation model in thematic discussion and enhance model workshop findings

land-use characteristics, or construct and demolish buildings. These interventions are simulated in real time, allowing participants to observe consequences for social structures, population dynamics, or environmental conditions. Participants can also inform simulation parameters through digital surveys before the simulation setup. The modeling workshop setting, featuring role play and graphical tracking of discussions and model runs, represents an indirect mode of interaction with the MSL.

3.2. PaSyMo Workflow

The MSL workflow consists of a four-step process (Figure 3) in which the MSL is adapted to the challenge ahead: (1) the assessment and requirement analysis, (2) the data acquisition and preparation, (3) the modeling phase including simulation model design and calibration, and (4) the workshop with stakeholders (in an interim exploration phase, surveys can be utilized to capture additional insights on agent or spatial perceptions).

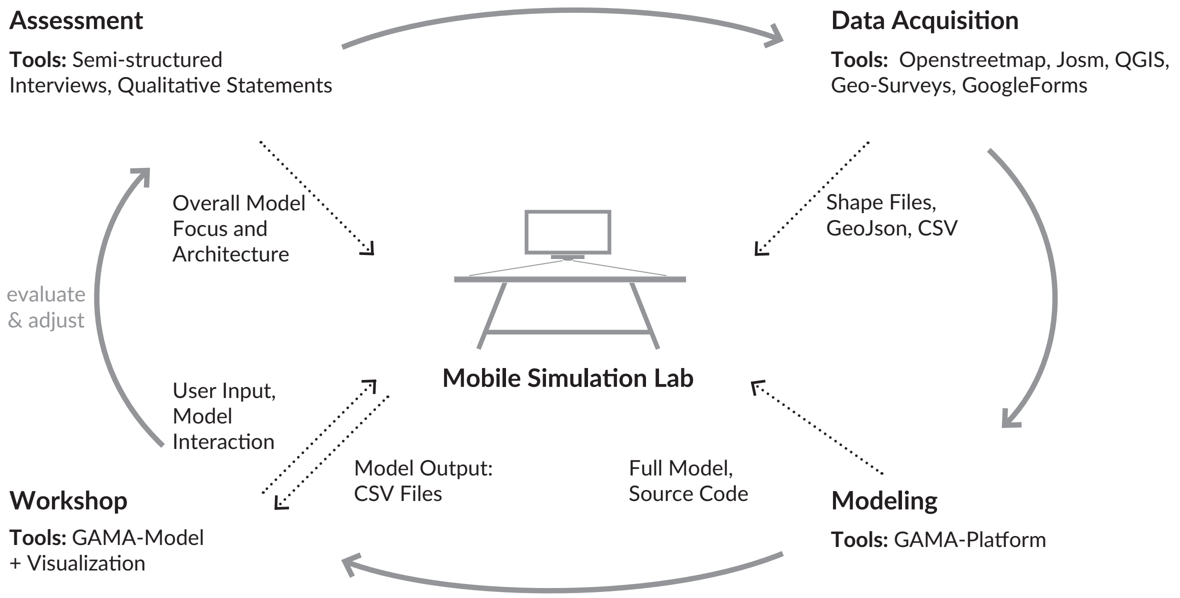

Figure 3. The four phases of the PaSyMo workflow.

The PaSyMo process starts with an *assessment* phase pursuing multiple objectives via desk research and field studies: researching a topic and local requirements, setting goals of the process, and conducting semi-structured interviews and field visits to gain expert insights from various points of view, such as needs of policymakers, expert knowledge, or the interests of citizen initiatives. Alongside the assessment, a model-concept draft is created that is continuously updated over several iterations, considering the results and feedback from field studies.

The second phase is *data acquisition* to create a virtual spatial representation of the target urban system (Figure 4). To this end, two main data sources are required: GIS data to construct the spatial dimension of the model, and census data to generate a synthetic population of agents for the simulation.

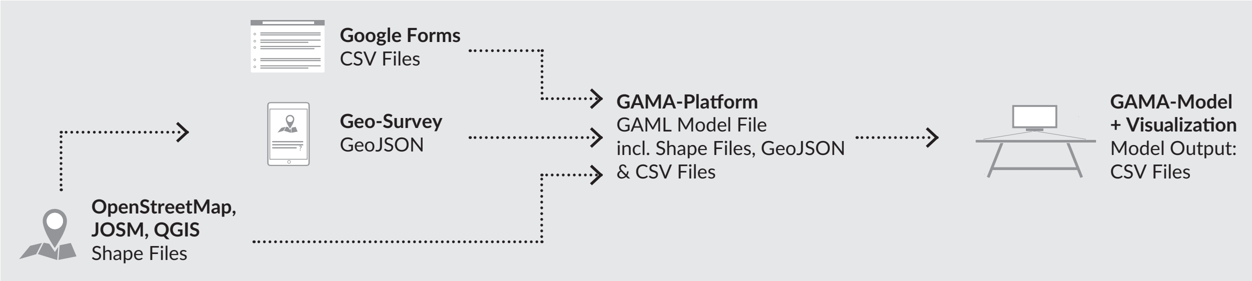

Figure 4. Data acquisition workflow.

The primary source of geospatial data is OpenStreetMap (OSM; https://www.openstreetmap.org), which provides open-access data in the form of nodes, paths, relations, and metadata attributes. The completeness of OSM data for the case study areas needs to be checked and, where necessary, improved through armchair mapping sessions using the JOSM editor (https://josm.openstreetmap.de). GAMA allows direct parsing of OSM files via its API, enabling seamless integration into the simulation environment. Additional preparation and editing of geospatial attributes performed in QGIS (https://www.qgis.org) ensures the datasets are cleaned, structured, and ready for import into GAMA.

On the demographic side, census data from official state providers (e.g., https://www.statistikportal.de) or municipal administrations was used to construct a synthetic population of human agents. Typically, population statistics are aggregated at the district level and stored as CSV files containing district names, identification numbers, and total inhabitants. Since PaSyMo uses an ABM approach, this data must be disaggregated to finer spatial units, such as apartment units in residential buildings, to accurately inform individual agent placement and characteristics. This process enables spatially explicit modeling of socio-demographic dynamics and interactions.

In addition to GIS and census data, the MSL supports the integration of geo-referenced survey data to incorporate stakeholder perspectives directly into the model. This can be achieved via an open-source application that generates JSON files from survey responses or by using tools such as Google Forms to export CSV data. These inputs can be dynamically imported into the simulation server during workshops, enriching the model with participant-generated knowledge in real time.

All model processes and GIS data are stored locally on the server, which ensures portability and reusability of the simulation environment. Compatibility with open-source software and widely available GIS data reduces technical and financial barriers, making advanced simulation accessible even in municipalities or citizen initiatives with limited resources or expertise.

In the *modeling* phase, a spatially explicit ABM is created in the GAMA platform. Each element of the city is translated into an agent with different abilities to interact or contribute information to other agents. Depending on the use case of the model, agents equipped with particular rules can be applied to the model with the aim of simulating phenomena such as migration patterns, rental price trends, or transportation (to name a few examples). GIS data can be imported to create a data-driven model of the urban area in question, containing building, traffic infrastructure, and land use information. Buildings, roads, and other shapes are created as separate agents with a 3D visualization that have properties and can be interacted with. Once the spatial realm is created, a synthetic population is implemented by placing software agents via iterative fitting of local population statistics, utilizing GIS attributes as a means of spatially explicit disaggregation (Moeckel et al., 2003). If, due to data scarcity, socio-economic data are not available for the testbed location, disaggregation is confined to accurately distributing households to apartment blocks, which are identified by land use types via their GIS attributes. Optional additional spatial layers can be added to the model to create special places of interest. For example, to inform them at a later stage using supplementary data generated during the workshop by connecting to web services like Google Docs or the PaSyMo server.

In the *workshop* phase, stakeholders of urban planning problems interact with the model (for specific examples, refer to the following section). The researchers and modelers stay in the background. They guide the group process and make on-the-fly changes to the model if necessary. The participants utilize the PaSyMo MSL as a common point of reference. Together, they discuss the topic by first engaging in rather open reflections of their personal beliefs and opinions. Once faced with the MSL, participants are then urged to become more explicit and operationalize their arguments in the form of quantifiable what-if statements that can be tested by simulation. The aim of this interaction between group discussants and the MSL is to increase transparency of the thought processes and mental models underlying stakeholders' perceptions of the planning problem, as well as to create a more scientific mindset where opinions become hypotheses to be tested rather than rigid solutions to which the stakeholder is committed.

In the last phase of the workshop, participants engage in collective meaning-making of the visualized simulation outcomes. They discuss what has changed, whether the issue has been addressed, and make sense of the causality between their input and the visualized effects. The researchers and modelers facilitate this discussion and provide insights into the causal mechanics at work in the MSL. The aim of this gamified interaction is to debate different perceptions and ideas of causal links inherent in the model and to improve the collective knowledge about the complex planning problem—a core idea of communicative urban planning. This approach is supposed to foster systems thinking and challenge partisan beliefs by forcing humans to think beyond simple one-cause one-effect explanations. It is important to mention here that workshop participants need to be guided not to interpret the simulation outcomes as unavoidable certainties, but as contingent what-if scenarios.

The selection of stakeholders that participate in the group process is important and should be appropriate to the planning problem at hand (examples in Section 4). The selection of participants should consider group size and diversity. While there is no prescribed limit on the number of participants, the group should be optimized for high performance through face-to-face exchanges (Pentland, 2012). That means it should be big enough to include multiple viewpoints while still allowing every participant to join the discussion in a "one at a time" principle (Schegloff, 2017). Like in every participatory process, the cooperation of stakeholders is context-sensitive. Humans who join the process might have competing interests that result in active conflicts. Attention should also be given to power asymmetries in the group since this strongly influences how topics can be discussed, which humans raise their voices, and how transparent participants are about their beliefs on a topic (Voinov et al., 2018).

4. Implementation Examples of PaSyMo

PaSyMo was designed to support urban development in small and mid-sized municipalities in the state of Brandenburg, which surrounds the metropolitan area of Berlin. Since the German reunification, municipalities in Brandenburg have faced tremendous transitional challenges. Steeply rising rents in Berlin, improved transportation infrastructure, and a movement towards more flexible working concepts such as remote work offer new growth opportunities for small and mid-sized towns in the state after two decades of shrinking populations following the fall of communism. However, considerable uncertainty makes urban planning in this dynamic environment challenging, calling for simulation-based scenario approaches. We thus had a good opportunity to test the frugal PaSyMo MSL in different workshop settings with varying degrees of participant involvement. Table 2 displays an overview of the cases, while Figure 6 conveys impressions of various workshops.

The research was of an exploratory nature, aimed firstly at testing the technological viability of the setup, but also providing us with an opportunity for some first observations regarding the usefulness of the approach in the context of the communicative planning paradigm, thus generating hypotheses to be more systematically pursued in future research.

The first case was aimed at estimating the impact of future development of inner-city mobility choices due to road usage changes in the town of Eberswalde, northeast of Berlin. The simulation model consisted of a virtual representation of the central district and its road network. The simulation implemented stylized daily schedules and commutes of virtual agents during repeating day cycles. The simulation model was based on the open-source simulation "Game IT" developed by Grignard et al. (2018). For the commute, the agents decide individually on what mode of transportation they take to travel to their next destination. The decision they make is dependent on the trade-off between their goals to minimize the time, effort, and cost of the trip.

The dynamics represented in the models and the impact of user interaction with the models are visualized in real-time on the table-top interface (Figure 5, left). The statistical output of the model showed data on the chosen mode of transportation (public transport, car, bike, or foot), and it kept track of different subsets of the local population (schoolchildren, students, employees, non-working adults, and pensioners). The simulation table served the heterogeneous group of participants (citizens, representatives from the local planning authorities, students, and researchers) as a common point of reference where adjustments to road usage changes were tested, compared, and discussed. The discussions were summarized in the form of three scenarios of the future development of inner-city traffic.

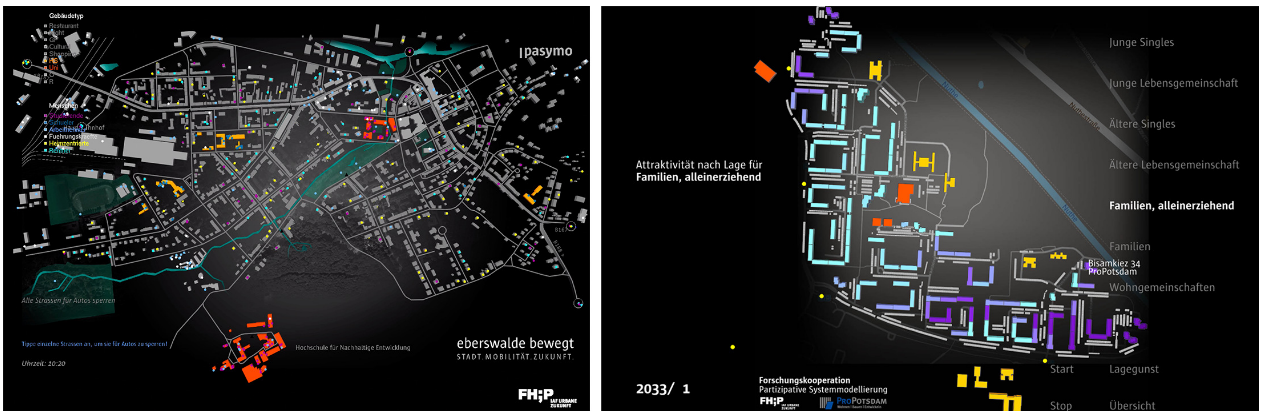

Figure 5. PaSyMo GUI showing the spatial simulation environment of the Eberswalde Models (use cases 1 & 2, left) and the Schlaatz Model (use case 3, right).

The second case addressed residential mobility and rising rents under a population-growth scenario. The simulation model consisted of a virtual representation of Eberswalde as buildings and households. During the simulation phase, the effects of different policies on the rent increase were simulated. Stakeholders count changes to a limited set of parameters that reflect the respective role, including spatial interaction on the projected map. Statistical output comprises changes regarding the composition of different household types in the building chosen on the map screen, building-specific flat numbers per size, calculated attractivity per household type, and the development of rents in the chosen building. When stakeholders agreed on a compromise, the model was run, and results concerning specific rent increases were plotted and added to the graphical workshop poster. The results of each model run were discussed, and three policy scenarios were developed. Participants were interviewed before and after the workshop. The results suggested that the developed workshop concept was well-received, the modeling principles were transparent and understandable, and the MSL format was accessible to the target group (general experts on urban development).

Table 2. Characteristics of use case workshops with increasing application focus.

Use Case No.	Thematic Focus	City of Use Case	Workshop Setting	Participants	Participant Involvement	Purpose
1	Inner-city mobility choices	Eberswalde	Municipal street festival and presentation in municipal administration	Citizens, representatives from local planning authorities, students, and researchers *n* = ca. 25	Presentation and discussion	Test spontaneous reactions and feedback on general modeling for urban development
2	Residential mobility and rent increase	Eberswalde	Expert workshop	Urban development experts from practice and academia, graduate students (M. A. Urban Futures) *n* = ca. 40	Active workshop participation, incl. survey input, role-play, and live model interaction	Test approach in custom workshop setting with hypothetical urban development task, discuss practicability with experts
3	Residential mobility and socio-demographic population development	Potsdam, Schlaatz neighborhood	Series of 4 expert workshops as part of a 6-month research cooperation with municipal housing corporation	Experts and CEOs from municipal housing corporation and several further housing cooperatives, researchers; Bi-weekly collaboration meetings: *n* = 2; Workshops: *n* = 5 to 10	Live model interaction, discussion	Test approach in real-world conditions for expert use and with real-world use case

The third application of the MSL was conceived as part of a collaboration with a municipal housing company in the city of Potsdam to study the refurbishment process of the Schlaatz neighborhood of approximately 9,500 inhabitants from 2020 to 2035. Over six months, several workshops were held to generate a common understanding among different company experts (CEOs, the Strategic Unit for Energy, Environment and Neighborhood Development, the Financial Department, and the heads of collaborating housing cooperatives) of the influencing factors and mechanisms that characterize the future development of the neighborhood's social structure. The model (Higi, 2019) showed a virtual representation of the Schlaatz neighborhood that was calibrated using data from publicly accessible statistical data and the company's database (Figure 5, right). The simulation allowed for intuitive real-time user interaction to test different scenarios and parameter settings: user interaction comprises the ability to explore different (dynamic) layers of visualization (property, energy consumption, state of refurbishment, wheelchair accessibility, and household type-specific attractivity according to the soft criteria mentioned above). The table-top interface allowed us to simulate the construction of new buildings and to add assumptions about possible groups of renters.

The interactive model visualization, including data from the company's different departments, led to participants expressing new insights and a more holistic view of the development project. Model interaction phases on the table revealed an "icebreaker effect" of the interactive touch-sensitive map projection—practitioners who were initially somewhat skeptical of an academic framing of their "daily business" became

Figure 6. Workshop setting and impressions. Top left: MSL Setup; Top right and bottom left: Use Case 2; Bottom right: Use Case 3. Sources: Pictures 1–3: Courtesy of Potsdam University of Applied Sciences, 2019; Picture 4: Courtesy of Nicole Stäbler, ProPotsdam GmbH.

more open to model discussion and interaction, discovering the ludic moment of exploring models and simulations.

5. Discussion

We presented the PaSyMo MSL as a frugal approach aimed at gamifying communicative urban planning with participatory ABM equipped with a tangible user interface. We presented three case studies, lending support not only to the technological viability of the setup but also allowing us to gain first exploratory experience with its application in a real-world context. This project has attracted actors from different domains, which has led to various follow-up projects in the infrastructure sector (e.g., Dametto et al., 2022), attesting to the face value of the approach in the eyes of urban planning stakeholders. Although we have only conducted limited formal user studies due to the exploratory nature of the case studies, our observations led us to formulate a few guiding questions for future impact assessment, which we discuss here.

One relevant design question is whether the MSL setup can indeed encourage creative and transparent communication. Across the workshops, especially in the third case, the tangible interface was perceived as an enabler for creative thinking and collaborative ideation. The hands-on nature of the MSL lowered participation thresholds and supported the shift from overtly relying on implicit assumptions to explicit communication and the convergence of assumptions. The possibility to interact directly with the model and observe outcomes in real time created a shared space for experimentation. Participants were able to test assumptions, make suggestions, and explore potential futures in a setting that blended the strategic with the ludic. These sessions made visible many ideas that would likely remain implicit in conventional formats. Here, future research should study more systematically our impression that the workshops with the MSL prompted a more experimental and creative mindset in the participants, opening the potential for more creative and effective solutions to the "wicked problems" of urban planning.

A key design concern was whether users would be engaged with the system and process. Participants' self-reported impressions, as well as the level of activity during sessions, suggest an increased motivation to participate in communicative planning groups with the MSL setup. Several participants stated that the simulation table helped them explore the topic more deeply, gain insights into the actors involved, and understand the conceptual background of the urban challenges under discussion. Particularly in the first workshop, some participants raised concerns about the representational quality of the model and expressed a desire for more empirical grounding. This feedback led to stronger data integration in the later sessions, including the use of municipal databases and disaggregated census data. Improved model calibration and increased transparency in how parameters were constructed helped mitigate concerns and enhanced participant trust in the process.

Finally, we assessed whether and how the MSL improves collaborative planning processes. The system was effective in providing a *shared* visual and spatial language that supported joint problem framing and exploration. Discussions became more grounded and explicit as participants adjusted parameters, compared scenarios, and debated the consequences of simulated outcomes. However, the sessions also revealed a recurring challenge: the risk of misinterpreting the simulation as predictive rather than exploratory. Despite repeated clarification, some participants saw model outcomes as projections rather than hypotheses. This techno-optimism needs to be actively addressed in participatory settings. It has yet to be proven that facsimile models—those that reproduce a targeted phenomenon as exactly as possible with the intention to make predictions of the target's future state—can be obtained, let alone provide accurate predictions. For now, it is more likely that models of social phenomena that exactly match observations will be rare and restricted to very special cases (Yang & Gilbert, 2008).

The prototype testing of PaSyMo led us to assume that social-psychological aspects of group dynamics play a crucial and too often underestimated role in public engagement initiatives. To better account for effects that potentially sabotage communicative planning actions, such as confirmation biases, we have concluded that a thorough socio-psychological impact assessment must be regarded as an integral part of participatory modeling. This could help to better understand which impact the tangible simulation can have in (re-)framing and (re-)shaping participants' perceptions of local issues, local urban planning discourses as a whole, and the making or breaking of trust between different stakeholder groups.

6. Conclusions

We have presented the PaSyMo MSL that combines ABM with a tangible interface to support human-centered discursive workshops. Based on the argument that such a gamified approach provides possibilities for fostering novel forms of communicative planning, we demonstrated how stakeholders performed impact and scenario analysis for development strategies while interacting with a digital city landscape. In that process, the MSL acted as a common point of reference, a test ground for envisaged projects, and a boundary object for increasing transparency and explicitness during communication, consultation, or deliberation. The interplay of open-source software, consumer hardware, and spatially explicit tangible ABM is a gateway to inexpensive solutions for integrated and collaborative decision-making in cities.

Fully aware of the exploratory nature of the described case studies and the considerable research needs outlined above, we nevertheless think that the PaSyMo MSL is a promising approach to complexity reduction to better deal with uncertainty in communicative urban planning. However, we need to be aware of the dangers of potential misinterpretation and manipulation that might arise from the use of simulation. By emphasizing the notion of participatory settings, we aim to use data, games, and simulations as tools for an unbiased systems-thinking pedagogy that enables genuine commitment and collaboration of heterogeneous urban actors.

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Conflict of Interests

The authors declare no conflict of interests.

Data Availability

An agent-based model supporting the findings of this study is published in Higi (2019).

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About the Authors

Timo Szczepanska is a researcher at NORCE Research and UiT—The Arctic University of Norway. He holds a PhD in social sciences on developing methodological approaches and participatory methods for combining games and agent-based models. His work focuses on simulation-based approaches for studying human behavior in complex adaptive systems. During the PaSyMo project, he worked as a researcher at the Institute of Urban Futures of the University of Applied Sciences Potsdam.

Max Priebe is a sociologist whose research focuses on strategic foresight in government action and the governance of innovation. He completed a doctorate in Science and Technology Studies and works as a project coordinator at Fraunhofer ISI. During the PaSyMo project, he worked as a researcher at the Institute of Urban Futures of the University of Applied Sciences Potsdam.

Leonard Higi is a research associate at the University of Applied Sciences Potsdam, Germany, and a PhD student at the Institute of Urban Planning, Brandenburg University of Technology Cottbus-Senftenberg, Germany. With a background in architecture, urban planning, and futures studies, his areas of interest encompass data use in urban planning.

Tobias Schröder is a professor of sustainable urban development strategies at the University of Applied Sciences Potsdam, Germany. He received his PhD in Psychology from Humboldt University Berlin in 2009. His research interests include human behavior in cities, innovation, change management, and computational social science methods.