

# Urban Transition Toward Environmental Sustainability: Instrumentation and Institutionalization of Co-Creation

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## Abstract

The transition in cities toward environmental sustainability requires transforming urban subsystems such as energy, transport, and waste infrastructure. Based on the frameworks of strategic spatial planning (SSP) and urban transition management (UTM), the urban transition is conceptualized as a long-term process in which stakeholders co-create a vision and a strategic plan, which is subsequently implemented in multiple relatively short-term projects transforming these urban subsystems. While co-creation is emerging in urban planning, ambiguity remains regarding the development and use of co-creation instruments in transforming urban subsystems. This article therefore has two aims: first, to develop a typology of co-creation instruments for urban transition planning and management; and second, to examine the institutionalization of their development and use. The article follows an iterative inductive-deductive search method to make an inventory of instruments, after which four main types are identified: participatory planning and communication tools, expert planning support systems, urban living labs, and virtual transformation labs. Several challenges in using these instruments are identified, including the need to acquire governance and digital skills, and to keep tools and data up to date. This article subsequently examines the capabilities that need to be institutionalized to support the use and development of these instruments across multiple projects. Capabilities needed are stakeholder engagement and collaborative governance, the participatory design and updating of digital tools, maintenance of urban subsystem and city development models, definition of transition scenarios and experiments, and interpretation of (simulation) results. Additional capabilities are needed to manage the project portfolio and facilitate learning within and across projects. Ultimately, a “Transition Planning Office” is proposed to institutionalize these capabilities and, by doing so, to complement UTM’s focus on independent vision and agenda formulation with sustained involvement in

long-term planning, and to support SSP's call for more strategic urban planning through project portfolio management and instrument use and development.

### Keywords

co-creation; environmental sustainability; institutionalization; instrumentation; living lab; planning support system; strategic spatial planning; urban transformation lab; urban transition management

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## 1. Introduction

Many cities around the world are engaged in the transition toward environmental sustainability (see e.g., the Global Covenant of Mayors), notably aiming for low greenhouse gas emissions, low energy consumption, clean transport options, adequate waste management, green building practices, and so forth. This urban transition is a long-term, complex process fraught with uncertainty in which urban subsystems such as infrastructure (e.g., energy, transport, waste), the built environment, and the green-blue ecological network are to be transformed to meet sustainability targets. However, most of these urban subsystems rely on costly infrastructure, capital goods, and complementary technologies, with entrenched use and support by institutions, which together cause a “carbon lock-in” (see e.g., Seto et al., 2016). *Incremental* innovations of the *existing* system generally do not suffice, and instead, a *radical* change of the system is required (Loorbach, 2022). Mitigation of and adaptation to climate change need to be integrated into urban design, land use, and urban planning praxis (Bai et al., 2021; Raven et al., 2018). This may also require changes to regulations, institutions, and public services to promote sustainable consumption and economic activities (Keivani, 2009; Talen, 2012). This radical change needs to be proactively governed (Wittmayer & Loorbach, 2016) by engaging the diverse set of stakeholders (e.g., urban planners, policymakers, public utility providers, local communities, construction companies) to co-create solutions to local particularities and to find trade-offs between conflicting interests. This resonates with planning theorists' calls for progressive participation (Healey, 2020) and transforming traditional planning to facilitate co-creation by engaging a broad range of actors (Albrechts, 2013).

Despite the increasing attention on co-creation, there is still considerable ambiguity (Brandsen & Honingh, 2018) regarding its operationalization in urban transitions. Contributing to this is the fragmented evolution of conceptual frameworks, the rapid emergence of a variety of instruments, and a lack of clarity on the role of urban planners and other stakeholders therein. As a conceptual basis for examining co-creation activities in urban transition, this article synthesizes two conceptual frameworks that extend beyond the traditional master plan and zoning regulations and redefine the role of expert planning professionals in this process. First, strategic spatial planning (SSP; Albrechts, 2004, 2013, 2015) integrates long-term vision formulation and short-term change projects with adaptive learning on both vision and operational project goals. Second, urban transition management (UTM) promotes the establishment of a transition team of change agents to co-create an agenda to develop radically different urban subsystems (Frantzeskaki, 2022; Frantzeskaki et al., 2018; Nevens et al., 2013; Roorda et al., 2014; Wittmayer & Loorbach, 2016). While SSP seeks to reform existing practices and instruments toward strategic, stakeholder-oriented planning, UTM is deliberately placed outside of existing urban planning and does not prescribe methods or instruments for the long-term management of individual projects or the portfolio thereof (see Wolfram, 2018, p. 111). In synthesis, the urban transition is perceived as a long-term process driven by a shared vision for the future city, whereby

this vision is realized through multiple, relatively short-term, co-created projects that transform urban subsystems. The tools, methods, and approaches for the co-creation of the urban transition process continue to evolve with the rise of new planning paradigms, theoretical conceptualizations, methodologies, data availability, and technical advancements. Not only are traditional planning tools being extended with new sustainability criteria and used in participatory planning, but also new instruments, such as living labs, digital twins, and city development simulations, are being developed. Moreover, applications of online platforms for participation, data-intensive analytical tools, and digital decision support systems are on the rise, also in urban transition planning. However, there is currently neither a comprehensive overview of instruments nor a clear understanding of how to adequately develop and use them in practice. As such, the article has two aims: to develop a typology of co-creation instruments and to examine the institutionalization of the development and use of these instruments in urban transition planning and management. First, the typology is developed by making an inventory of instruments according to an iterative inductive-deductive approach (see Mayring, 2000) and subsequently classifying and clustering them into types. Hereby, the instruments are assessed on three dimensions: whether they focus primarily on qualitative information exchange or rather quantitative data analysis using digital tools; whether they are expert-led or rather follow a participatory or collaborative governance approach; and whether they support short-term decision-making or rather long-term strategic planning, experimentation, and learning. Based on this classification, four distinct types of instruments for urban transition are discerned: participatory planning and communication platforms, expert planning support systems, urban living labs, and virtual transformation labs. In addition, the article identifies specific challenges in using digital co-creation tools, particularly in planning support systems and virtual transformation labs. Second, given the long horizon and the multiple projects in which co-creation instruments are to be used, the article examines the institutionalization of their development and use. Urban transition planning requires building capabilities not only for stakeholder engagement for vision formulation and strategic planning, but also for the participatory design, maintenance, and use of urban subsystem and city (development) models, as well as the analysis of (simulation) data. Moreover, given the rapid evolution of co-creation initiatives and instruments, planners need capabilities to monitor and learn within and across projects (possibly in other cities) as well as to manage the overall portfolio of transition projects. This article thus contributes an operational perspective on co-creation instrumentation and institutionalization to the existing literature on urban transition and planning theory. While not a primary aim, the article also proposes a “Transition Planning Office” (TPO) as the institutionalization of these capabilities. The TPO complements the integration of strategic planning proposed by SSP and the deliberately independent transition arena proposed by UTM.

The structure of the remainder of the article is as follows. Section 2 provides the conceptual framework for the co-creation of urban transition and builds upon the SSP and UTM approaches to outline the purpose and challenges of instrumentation and institutionalization. Section 3 presents the typology of instruments, explains the methodology used to develop this typology, and discusses challenges in the implementation and adaptation of these instruments. Section 4 discusses the institutionalization of transition planning and management, focusing on capabilities required for stakeholder governance and using instruments within and across the range of urban subsystem transformation projects. Section 5 provides conclusions and insights into the instrumentation and institutionalization of co-creating transition planning and management.

## 2. Conceptual Framework

### 2.1. Co-Creation of the Urban Transition to Environmental Sustainability

As described above, urban subsystems may be in a carbon lock-in (cf. Seto et al., 2016), such that their transformation to become environmentally sustainable needs to be proactively governed (Hölscher, 2018; Loorbach, 2022; Wittmayer & Loorbach, 2016) and may require changes not only to infrastructure, but also to regulations, institutions, and public services (Keivani, 2009; Talen, 2012). However, alternative transformations may exist. For instance, air pollution from transportation can be reduced by introducing congestion pricing during peak hours, implementing ride-sharing systems, enhancing public transportation, restructuring the road network, and making cities walkable. Similarly, CO<sub>2</sub> emissions from energy consumption can be reduced through energy-saving campaigns, subsidizing smart appliances, switching to green electricity in public buildings, promoting the purchase of solar panels, subsidizing building insulation, and imposing stricter building standards. Which options are feasible and preferred may depend on local circumstances, stakeholder capabilities and interests, as well as interrelations between transition solutions.

The diversity of stakeholders (e.g., policymakers, public utility providers, local communities, companies, investors) and their different interests make the transformation of urban subsystems a potential source of conflicts. Breaking out of the carbon lock-in therefore requires the co-creation of transformative solutions with trade-offs that are acceptable to these stakeholders. Arguably, the government has both the mandate and responsibility to engage these stakeholders and facilitate this co-creation process. This is also in line with the broader trend toward greater involvement of stakeholders in governmental decisions in general, and of stakeholder engagement and participatory governance in urban planning in particular (Healey, 2020). Stakeholders are not merely involved for tokenism or legitimization but are genuinely delegated decision-making power (Albrechts, 2013; Fugini et al., 2016; Leino & Puumala, 2021). Co-creation thereby leads to solutions that are neither imposed by expert decision-makers (top-down) nor driven by interest groups, citizens, or powerful stakeholders (bottom-up) but rather by engaging a variety of stakeholders across hierarchical relationships (Leino & Puumala, 2021).

However, in general, the concept and instrumentation of co-creation are still ambiguous and emerging (see e.g., Brandsen & Honingh, 2018). The understanding of what co-creation is (and could be) in the context of the urban transition is rapidly developing with (a) the conceptions of the urban transition in terms of goals, phases, and tasks, (b) the various perspectives on the transition-related activities and the role of various institutions therein (see SSP and UTM), and (c) the variety of operational instruments, methods, and approaches.

As discussed in the following subsections, the urban transition is seen as a long-term process driven by a co-created vision and development agenda, notably featuring relatively short-term projects that transform urban subsystems (infrastructures, utilities, services, built environment) aligned with that vision. As such, co-creation is understood as a governance approach in which an “urban transition agent” collaborates with stakeholders to formulate a shared vision and roadmap for urban developments. However, over time, new challenges and opportunities may arise, and specific developments may need to be deferred or adjusted. Given its inherent complexity and uncertainty, the transition process cannot be tightly planned but instead features experimentation, monitoring, learning, and adaptation both within and across projects. This requires alternative governance structures not only for the initial formulation of the vision and agenda but also to

facilitate the long-term engagement of stakeholders in co-creation activities (see e.g., Mahmoud et al., 2021). Thus, in the context of urban transition, co-creation is de facto characterized by the instruments applied to a range of tasks and the institutionalization of the involvement of stakeholders. The next subsections discuss key conceptual frameworks for planning and managing urban transformation, followed by the outlines of the instrumentation and institutionalization of co-creation within these frameworks.

## 2.2. SSP for Sustainability

Urban planning has evolved from being an authoritative, regulatory approach with institutionalized, government-led urban development practices to an approach that uses stakeholder engagement, participation instruments, and various governance modes (Faludi, 1973; Healey, 2020). SSP emerged as one of the responses to the dominant expert-led, top-down approaches. As Albrechts (2013, p. 52) summarizes:

Strategic spatial planning is looked upon as a transformative and integrative public sector-led, but co-productive, socio-spatial process through which visions or frames of reference, the justification for coherent actions, and the means for implementation are produced that shape, frame and reframe what a place is and what it might become (Albrechts, 2010: 1117; Motte, 2006; Oosterlynck et al., 2011; Van den Broeck et al., 2010).

SSP revolves around participatory involvement of empowered citizens and a broader set of stakeholders (firms, environmental groups, consultants) and translating these visions into short-term actions (Albrechts, 2004). Moreover, rather than merely soliciting citizens' opinions to subsequently have professionals do the planning and projects, these citizens are involved in "agenda setting, problem formulation, the shaping of the content of policies, plans and projects and the delivery as well" (Albrechts, 2013, p. 53). SSP thereby challenges existing relationships and rather seeks to empower and include innovative change agents in an adaptive, co-creation process (Albrechts, 2013, 2015). In SSP, a shared, long-term vision is co-created and subsequently implemented in short-term projects, adapting these in continuous learning while involving stakeholders to mobilize networks and capabilities.

Urban development has traditionally been (and generally still is) regulated through master plans and zoning regulations, and even though these may, in some cases, cater to sustainability goals (Jepson & Haines, 2014), transforming existing energy and transport infrastructure to meet these goals would typically necessitate radical redevelopment. In practice, urban planning does use methods and systems to reform land use and energy and transportation infrastructure, albeit typically not from a sustainability transition perspective (Walsh, 2018). Generally, the planning of urban subsystems is path-dependent rather than path-breaking (see e.g., Malekpour et al., 2015). Although SSP should be integrated into regular urban planning approaches (Wolfram, 2018, p. 111), it is intended to be complementary to, rather than a substitute for, the common planning tools such as land use, master planning, or zoning.

## 2.3. UTM

Unlike SSP, UTM explicitly starts from the premise that radical change is needed and that the ideas for this are best formulated in a "safe space" sheltered from the influence of the actors within the unsustainable pre-existing system. It advocates bringing together a deliberately broad variety of "frontrunners" to develop

a shared understanding of the urban transition challenges, formulate a collective, long-term vision for the city, and translate this into flexible pathways with short-term active experimentation and learning (Wittmayer & Loorbach, 2016; Wittmayer et al., 2018). As described in detail in Roorda et al. (2014), an initiating agent kickstarts the formation of a “transition team.” This team drives the management process, analyzes the urban subsystems to be transformed, and conducts a stakeholder analysis to invite change agents in a “transition arena.” This transition arena is a small, diverse group of change agents from various backgrounds (e.g., municipality, companies, research institutes, citizens) and domains (e.g., energy, transport). Over the course of several meetings, the arena participants formulate the transition challenge, problem framing, and visions for the future. Using these visions, arena participants engage in backcasting methods to define possible pathways to realize the visionary image (such as a roadmap of actionable goals towards transforming the city). Transition experiments are used to explore and assess the viability of radical changes to resolve transition challenges. The action plans and their associated transition experiments used to realize long-term visions and pathways are documented in the transition agenda. This agenda encompasses “a strategic perspective—a transition narrative—that can be used as an anchor point for new initiatives and policy” (Roorda et al., 2014, p. 32). This agenda is (merely) a means to engage the wider audience and influence the agenda of others, e.g., by organizing networking events, by seeking publicity, by integrating elements into existing processes, or by introducing transition concepts and practices within municipal organizations.

Since the agenda merely sets the direction for the long term and guides actions in the short term, the next step would be to initiate transition projects. Such projects hinge on actors that gather the required competences, funding, and resources to operationalize the ideas in the agenda. This is a “working group” of actors responsible for project management and involving companies and policymakers. Moreover, a coordinator is required to facilitate ongoing engagement and reflection among actors involved in the transition process.

Despite the name of the approach, transition management does not prescribe methods or instruments for the *long-term* management of single initiatives, let alone the portfolio of transition projects. Indeed, the transition arena is just a temporary, short-term process at the front-end of the transition, and is foreseen to cease to exist after formulating the agenda and engaging the wider audience. Nonetheless, there is a lack of clarity about the actual institutionalization of the long-term transition activities. In addition, at some point, moving forward with changes to a socio-technical system or public service becomes a matter of design, engineering, project planning, procurement, and execution. The room for adaptation and co-creation tends to diminish. So, it seems that, to a certain extent, short- and mid-term urban planning methods and activities are expected to exist side-by-side with the long-term transition perspective.

#### **2.4. Instrumentation and Institutionalization of Co-Creation in Urban Transitions**

Both the long-term urban development vision and agenda as well as the portfolio of relatively short-term projects transforming urban subsystems are co-created. Each project is a transition challenge with a variety of solutions to consider. Currently, urban planners take the long-term master plan, land development plan, and zoning regulation as guideline. So, arguably, urban planners lack a toolkit of instruments to research, develop, and implement transition solutions in actual urban planning practice (cf. van de Ven et al., 2016). In part, this may be due to an inherent tension between long-term, “vision-pulled” transition processes that emphasize experimentation and reflection and the relatively short-term urban planning and design projects that merely

extrapolate from existing developments. Clearly, striving for the materialization of plans is at odds with keeping options open and postponing changes that are costly to reverse. So, this experimentation and analysis occurs prior to the planning, requiring additional instruments and arrangements. Neither core UTM nor SSP literature is explicit about instrumentation for analysis and decision-making. Moreover, core UTM literature refrains from discussing the institutionalization of front-end vision formulation, long-term process management, or short-term practical planning activities.

Despite their commonalities, both SSP and UTM have their own instrumentation and institutionalization requirements. Notably, UTM requires qualitative support for radical innovation, roadmap backcasting with short-term experimentation, monitoring, learning, as well as adopting grassroots initiatives. In contrast, since SSP is integrated into existing planning practices, it may have more use for long-term data and extrapolated trends and means for adjusting existing policy programs and zoning regulations. Moreover, co-creation with stakeholders far beyond regular planning commissions is prominent in both, so instruments and practices need to be developed in any case. Either way, given its novelty, complexity, and scale, the urban planning praxis has to develop “competences for designing transition management processes in cities and engaging with multidisciplinary knowledge in solution-seeking processes” (Frantzeskaki et al., 2018). Urban planning offices need to learn how to set up, develop, plan, and ultimately manage the execution of these transition projects. In the following two sections, both instrumentation and institutionalization for co-created transition are examined in detail.

### 3. Instrumentation of Transition Co-Creation

Over the past decades, the toolkit of instruments in urban planning has been evolving, notably in response to changes in aspirations, considerations, and responsibilities in planning theory (Allmendinger & Tewdwr-Jones, 2001), the rise and fall of movements (Garde, 2020), and the emergence of urban ideals such as the eco-city, walkable city, 15-minute city, etc. Moreover, new instruments have been developed leveraging digital technology and its modeling and decision-support capabilities, such as the smart city and digital twin city (see e.g., Batty, 2001; Silva, 2010). In addition, there has been a rise in online platforms for citizen participation in general (see Ragi Eis Mendonca & De la Llata, 2023; Rodriguez Müller, 2022) and urban planning in particular (see e.g., Abdalla et al., 2016; Ertiö, 2015; Falco & Kleinhans, 2018; Giannoumis & Joneja, 2022; Hovik et al., 2022). However, as discussed in the previous section, the co-creation of urban transformation requires additional instruments, particularly for at least two distinct process steps. Firstly, there is co-creation in the formulation of visions and the agenda to develop the envisioned city. The latter could be a roadmap of actionable goals and tasks based on backcasting, expert assessments, or analysis with a (computational) city development model. Secondly, there is co-creation of a variety of projects to transform urban subsystems (energy, waste, transport, blue-green ecological network), each of which requires analysis, decision-making, practical planning, and actual construction. It is conceivable that certain parts of the city development analysis in the first step are deferred to the more incremental, piecewise analysis in the second step. Particularly in SSP, the agenda readily sets outlines for activities for stakeholders in planning change. In UTM, the agenda outlines radical changes formulated by change agents, but leaves room for experimentation and learning, and thus needs to facilitate processes to do so. So, arguably, the toolkit for urban transition requires instruments for participatory vision formulation, analysis of the impacts of changes, co-creation of individual transformation projects involving different sets of stakeholders, and, ultimately, specification and execution of plans with room for experimentation and learning. This section



takes stock of the current toolkit of instruments for these process steps, specifically aiming to distinguish “types” of instruments based on their properties.

### ***3.1. Three-Dimensional Spectrum for Instrument Classification***

The selection and subsequent classification of instruments should be based on their (potential) use throughout the urban transition process, particularly in co-creating (the vision and plans for) projects and their implementation. Notable efforts have been made to map instruments to the various phases in the (short-term) urban planning process. Tasks and responsibilities in the planning and development process are often structured into consecutive phases (see e.g., Hopkins, 2001, p. 191), in each of which different instruments are used (see e.g., Siems, 2023, p. 53). Generally, a planning process consists of the following phases: (a) system analysis (using instruments for information and data collection, statistical analysis, and mapping), (b) collaborative goal setting (using instruments for brainstorming, preference analysis, and dealing with trade-offs between interests), (c) making action plans (e.g., using what-if analysis, cost-benefit analysis, roadmapping), and (4) project implementation and management. For long-term transition processes consisting of a multitude of subsystem transformation projects, activities can generally be separated into two broad phases: a phase of vision formulation and strategic planning followed by a phase of implementing a series of projects. In UTM, these projects take the form of experiments with monitoring, reflection, and provisions for adaptation. As such, one of the key dimensions of interest is whether instruments are of use in short-term urban transformation projects or rather support long-term planning, experimentation, or city development concerned with multiple short-term projects. Note that whether tools are applied over a longer time horizon or not has implications for the design and maintenance of these instruments, as well as for procedures and practices for updates based on intermediate developments.

In addition, there is ample literature on developments in instruments for two more dimensions. Particularly noteworthy is the increase in the use of digital tools (see e.g., Lieven et al., 2021; Staffans et al., 2020). This trend highlights the relevance of positioning instruments along a methodological-analytical dimension, ranging from low-tech tools for collecting, exchanging, and analyzing qualitative information and stakeholder perspectives to high-tech tools for quantitative, data-rich analysis, simulation, or optimization.

Moreover, planning instruments changed substantially during the “communicative turn,” when stakeholder engagement, participation, and other governance modes came into focus (Faludi, 1973; Healey, 2020). Thus, the third dimension pertains to the governance mode of instruments, which ranges from being applied by experts for top-down decisions (as in rational-comprehensive planning, for example) to involving a variety of stakeholders such as urban planners, municipal governments, residents, utility companies, and construction firms in co-creation. There is also bottom-up, grassroots-driven change (e.g., tactical urbanism, transition towns), but strictly speaking, this is not an instrument that can be actively wielded. However, participants in such grassroots movements could be invited to join the transition arena. Moreover, transition planners may cultivate such movements and adopt successful initiatives for wider co-creative application.

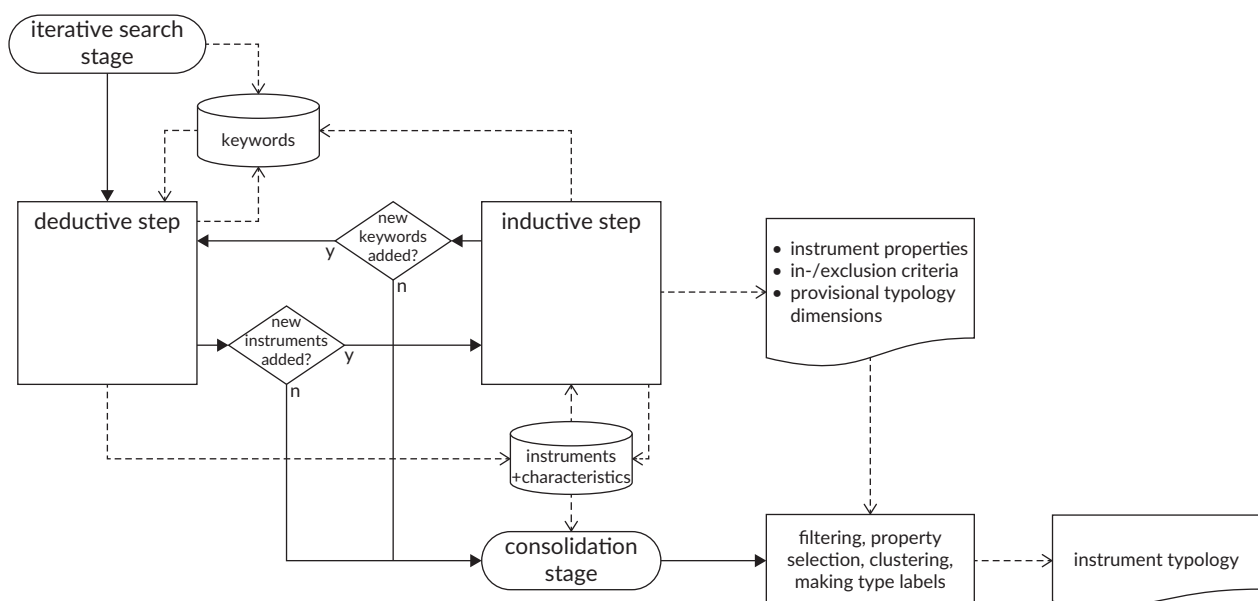
In conclusion, instruments for co-creating urban transition can be positioned within a three-dimensional spectrum: (a) from qualitative, conceptual, data-extensive, low-tech instruments to quantitative, data-intensive, high-tech instruments; (b) from hierarchical, expert-driven planning to collaborative planning with stakeholder engagement; and (c) from short-term, singular projects to long-term transition agendas.



### 3.2. Methodology for Instrument Identification, Characterization, and Typology Formulation

The first aim of this article is to formulate a typology of instruments that are either already used or suitable for use in the co-creation of the urban transition. However, finding and identifying these instruments is challenging because the conceptions of the transition process, the planning of urban transition projects, and the usage of co-creation instruments are all relatively recent and therefore possibly insufficiently reported. Consequently, instrument designations and terms used vary across disciplines and stakeholders. Moreover, instruments differ substantially in nature (ranging from digital tools to participation methods to governance frameworks), and many exist that have not yet been applied in urban transition planning and management. City planners, consulting agencies, applied research institutes, and other actors are engaged in developing new instruments, so the entire toolkit, its applications, and associated keywords continue to evolve. Consequently, what one is searching for changes with insights from what is being found.

Given these challenges, this article adopts a structured exploratory snowballing approach based on selected principles of qualitative content analysis, particularly iterative deduction-induction, content interpretation (for keyword selection), and progressive typology development (Kluge, 2000; Mayring, 2000). The approach consists of two stages: iterative search and consolidation. The search alternates between a deductive step, in which keywords and sources are used to identify new instruments, and an inductive step, in which content analysis of instrument descriptions expands the keywords and sources used next. The keywords include both designations of actual instruments as well as generic properties that describe their characteristics and applications. In conjunction with the expansion of the set of instruments and progress in understanding their properties and applications, the (conceptual basis for the) selection and typology of instruments is also gradually refined (see notably Kluge, 2000, on integrating typology discovery in qualitative content analysis). Ultimately, there is a consolidation of the types of instruments. The methodology for instrument search and type identification is depicted in Figure 1 and described below in detail.



**Figure 1.** Search stages and steps in the identification of instruments and typology formulation.

The iterative search for instruments alternates between deductive and inductive steps. In the deductive step, the search is conducted using (combinations of) keywords associated with co-creation, governance methods, digital tools, conceptual approaches, etc., looking for instruments that are or may be used in urban transition. This is aimed at creating a broad, diverse inventory. Initially, the list of keywords for search is based on the prior literature study. The search commenced in several directions: one on communication with and participation of stakeholders (using keywords such as “participat\*”, “engag\*”), one on digital tools (e.g., “digital planning,” “digital platform,” “GIS”), and one on governance forms (e.g., “governance,” “expert,” “grassroots”). In general, these keywords were combined with keywords on the transition itself (e.g., “sustainab\*”, “green,” “environment\*”), and spatial context (e.g., “urban,” “city,” “town,” “metropol\*”, “region\*”). One general and two academic literature search engines (Scopus, Google Scholar) were used. Initially, primarily academic peer-reviewed literature was searched, but over iterations, this got expanded with conference proceedings (notably for digital tools), gray literature (consulting reports, white papers), and websites of (networks of) municipalities, (applied) research institutes, etc. Each discovered instrument was recorded in a database for further in-depth inquiry.

In the inductive step, specific designations of instruments (e.g., “citizen participation,” “living lab,” “DIPAS”) are used for in-depth search to add a description, references to academic literature, and links to applications to the records in the database (occasionally also found in gray literature, websites of research institutes or municipalities, and so on). Content analysis of descriptions of the instruments and applications occasionally results in new instruments to be added for further in-depth analysis but also alternative keywords or new sources. In-depth search may also lead to merging records of highly similar instruments. As part of the inductive step, specific values were assigned to various instrument properties, such as Arnstein’s ladder of participation, actors involved (the organizer and main participants), frequency of use, time interval of expected impact, and the direction, purpose, and type of information exchange. For most of these properties, serious attempts were made to characterize all instruments so that these properties could be used in devising a typology. After each inductive step of in-depth analysis of additional instruments, the authors discussed properties of instruments (and whether to add new properties for potential use in the typology later), instrument in- and exclusion criteria, and revision of inductive search directions, sources, and keywords.

This iterative process culminated in the identification and characterization of a wide variety of instruments, ranging from generic communication and voting tools, to early-stage participatory vision formulation and advanced decision-support tools for urban subsystem design and project planning. The iterative search stopped when newly identified instruments were mere variations or applications of those already in the dataset (cf. Saunders et al., 2018). At that point, the aim of finding the main types of instruments was presumably attained.

The subsequent consolidation stage focused on finalizing the instrument typology by first filtering instruments and then selecting properties for clustering into types. After the search stage, the dataset still contained numerous instruments recorded for further in-depth analysis, but for which limited evidence of active use for transition planning or management was found (e.g., “citizen science,” “hackathon”). The filtering kept only instruments that can be used for formulating visions (e.g., “town hall meetings”), analysis of city developments (e.g., “using models,” “expert panels”), setting actionable goals and planning tasks (e.g., “backcasting,” “roadmapping”), or running projects (e.g., “living labs”). Since properties added during the iterative phase were not equally relevant, a subset was selected for clustering instruments into types. Several different subsets of properties were already considered for clustering during the iterative

stage. However, ultimately, the three key dimensions discussed in the previous section emerged as the basis for clustering, with one based on theory (time horizon) and the other two reflecting observed trends in instrument development (participation, digitalization).

### 3.3. Types of Instruments

The inventory of instruments led to the following four distinct types in the three-dimensional spectrum (see Figure 2).

#### 3.3.1. Participatory Planning and Communication Platforms

The most generic type is that of communication and participation instruments used for information exchange, soliciting feedback, and collaboration in the formulation of strategies and plans without using computer models, advanced data-analytical means, or any need for advanced digital skills or expert domain knowledge. At its core, urban planning often has a regulatory role in which a planning or zoning commission (typically composed of city council members, officials, and sometimes advisors) reviews building proposals to ensure alignment with zoning, environmental guidelines, and community objectives as outlined in master plans and development strategies. Formulation and regulation used to be the responsibility of urban city planners and experts. However, ever since the “communicative turn,” there has been a more explicit focus on collaboration and participation in urban planning (Healey, 2020). Prompted by actors seeking to change land use, by developments such as demographic or economic growth or decline, or following a broader call for mitigation and adaptation to climate change, urban planners may involve a wider set of stakeholders in the formulation of the urban development vision, strategies, regulation, and plans (see e.g., Hopkins, 2001). To this end, there is a large toolkit of participation instruments particularly suitable for making an inventory of transition challenges or formulating visions at the outset (e.g., focus groups, surveys, town hall meetings, citizens’ assemblies, deliberative mini-publics, citizen councils/panels, planning cells, and community forums). On a variety of such participation formats, see Nanz and Fritsche (2012) and OECD (2020). Already actively used in later stages of urban redevelopment projects, city planners also have a toolkit for engagement with the general public and public communication tools (e.g., interactive exhibits, billboards, outdoor photo exhibits, scaffolding scrim). More recently, tools for online or offline digital participation (with labels such as e-participation or digital democracy) have emerged that seek to engage a larger and possibly broader group of citizens in policymaking and co-creation of public services (Ragi Eis Mendonca & De la Llata, 2023; Rodriguez Müller, 2022). Also for participation in urban planning, there are various online platforms (Abdalla et al., 2016; Giannoumis & Joneja, 2022; Hovik et al., 2022), offline digital tools, and apps (Ertiö, 2015; Falco & Kleinhans, 2018). There are numerous examples of how digital city platforms are used in participatory urban development and design (see e.g., Galassi et al., 2021; Giannoumis & Joneja, 2022; Lieven et al., 2021; Noennig et al., 2023). Given the novelty of such tools, the formulation of guidelines for online participation in urban planning is due (Afzalan & Muller, 2018; Hofmann et al., 2020).

Generally, participation instruments differ in the degree of engagement and actual decision-making power of participants (Arnstein, 1969). Some of the tools seem to be more suitable for consultation than genuine co-creation processes with community members and other stakeholders. In contrast, UTM focuses on instruments for co-creation with a deliberately picked set of *change agents* (e.g., roadmapping, formulation of a transition vision and agenda in the transition arena, collaborative policy formulation in a policy lab). Central

in transition management is also the element of experimentation and learning in a real-world setting which forms the basis for the second type of co-creation tool.

### 3.3.2. Urban Living Labs

There are several instruments for medium-term, real-world experimentation and co-creation, such as Reallabor (Schäpke et al., 2017), Urban Living Lab (Aernouts et al., 2023; Bulkeley et al., 2016; Mahmoud et al., 2021; Voytenko et al., 2016), Urban Transition Lab (Nevens et al., 2013), and Community Design Charrettes (Lennertz & Lutzenhiser, 2017; Roggema, 2014). We will use the term “urban living lab” as the general term to refer to this kind of instrument. Such urban living labs are concerned with ongoing participation, experimentation, and learning to find and test local solutions to societal challenges in real-life settings (Bulkeley et al., 2016; Nesti, 2018; Voytenko et al., 2016). However, urban living labs differ substantially in their goals and forms of the co-creation process (Nesti, 2018; Puerari et al., 2018). Moreover, some initiatives, such as transition towns (Connors & McDonald, 2011), are arguably a form of living lab, though arising from a grassroots movement or a bottom-up community-led or corporate frontrunner-led initiative, rather than a top-down initiative of researchers or urban planners. Given the open concept of urban living labs and the extended time interval over which such labs may persist, participants may also use other types of instruments (see e.g., the mapping of instruments to elements of the urban transition lab in Nevens et al., 2013, p. 116). This gives rise to hybrid forms, such as living labs using digital co-creation tools (Lieven et al., 2021; Mačiulienė & Skaržauskienė, 2020). However, practically, whenever such local, experimental, and temporary tactical urban development initiatives are considered successful, further diffusion and implementation would require at some point in time more expert-driven urban planning, adjustments to regulations, and actual construction project management. So, experimental co-creation leads the way for professional urban planning, which is rather the next type of instrument.

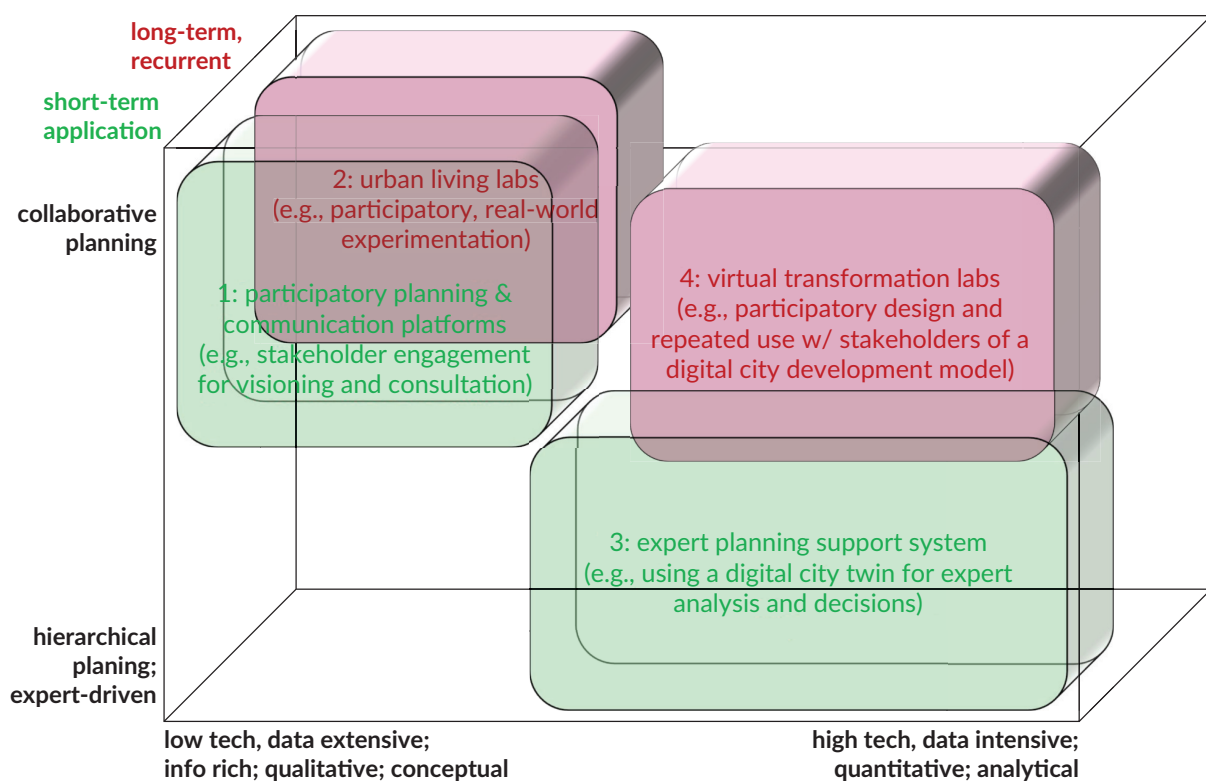
### 3.3.3. Expert Planning Support Systems

There is a toolkit used by urban planning professionals for short- to mid-term urban planning and design. The more traditional instruments of land use, master planning, and zoning ordinances are still used, albeit often also modernized. Planners use not only generic digital tools (e.g., QGIS, SketchUp, digital land use maps), but also data-intensive digital tools and systems for planning support (Geertman & Stillwell, 2004, 2009). Over the last few decades, these tools have advanced significantly, driven by developments in technology, data science, and the increasing availability of (real-time) data. A prominent advancement is the integration of GIS-based digital twins in tools for transportation and transit planning (e.g., TransCAD, TBEST, Hastus, PTV Visum), risk and resilience assessment (e.g., flood, heat, or disaster scenarios), and urban development simulations (e.g., UrbanSim, ArcGIS CityEngine). Modeling the urban subsystems typically requires the input of trends, scenarios, or models of demographic development, travel behavior, citizen preferences, etc. (see e.g., Landis, 2012), using, for example, agent-based models (Huynh et al., 2015; Namazi-Rad et al., 2017). Such tools support decisions on land use, locations for amenities, provision of public services, etc. Planners also have an interest in a digital twin model that represents *the actual state* of a focal city, sometimes even showing real-time data, such as on mobility patterns, energy consumption, etc. (see e.g., Anttiroiko, 2021; Gil, 2020). Such digital twins may even use real-time data collected in “smart cities” for operational management (e.g., of traffic flows) and computational urban planning (Douay, 2018; Geertman et al., 2019; Goodspeed et al., 2023). Such support tools can be used to identify challenges (e.g., traffic bottlenecks, heat islands), opportunities

(e.g., solar irradiance), and evaluate *incremental* changes (e.g., locations of schools, small transport network changes). These features make such tools suited for communication and collaborative planning with residents, firms, and other stakeholders. That said, despite their sophistication, these tools are inherently limited when it comes to planning for long-term, transformative urban change. After all, historical or present-day data on current conditions such as mobility patterns and energy usage have limited value in projections about the city in radical transformation scenarios. Therefore, these digital twin-based support tools are suitable for studying and planning *incremental* change, but not for visionary, radical transformation. This calls for the fourth type of instrument.

### 3.3.4. Virtual Transformation Labs

These instruments are virtual or physical laboratories for stakeholder involvement, collaborative planning, and decision-making using digital or hybrid physical-digital city models for long-term transition planning. The dividing line between the planning support tools discussed before and the transformation laboratories for virtual city development lies in the latter's persistent focus on multi-stakeholder interaction for strategic decisions and the ability to conduct radical, virtual experiments and scenario analysis over the long term. Virtual transformation labs use a flexibly configurable digital city development model to examine the impact of changes to the city (e.g., built environment, transportation network, green-blue infrastructure), notably using simulation, with the explicit intention to evaluate deliberate, radical changes, conduct "what-if" experimentation, and support formulation of visions and strategic planning. Examples of the latter are CityScope (by MIT; Alonso et al., 2018), Cockpit for Collaborative Urban Planning (HafenCity Hamburg, Austrian Institute of Technology, MIT Media Lab), Smart Region Lab (Hochschule Luzern), and the Decision



**Figure 2.** The four types in the three-dimensional spectrum of transition instruments.

Theater (Arizona State University). Although the technology and participation method are generic, the geographical scope, problem and system definitions, as well as building the network of change agents involved are time- and resource-intensive, so consequently mostly place-specific models and labs emerge. In these examples, the research institute, the city development model, and the main visualization platform are closely associated. Moreover, the content of the models, the interaction and interface of the visualization platform, and the use in and content of workshops are typically designed in participation with stakeholders. In the cases studied, the laboratories and underlying city models are not finished but continue to be developed for specific (applied) research projects. The development and application of these tools are therefore part of “action research.” In real-world living labs, the progressive application and scaling up of experiments must be approached prudently, subject to monitoring and reflection, and with options for roll-back. In virtual laboratories, in contrast, experiments can be large-scale and radical, though their impacts are, of course, based largely on assumptions and simulations rather than observed outcomes.

### 3.4. Implementation Challenges of Digital Instruments

The descriptions of the four types of instruments contain indications on how they can be used in the co-creation of transition. However, the use of *digital planning support tools* (Type 3 in Figure 2) and *virtual transformation labs* (Type 4) is relatively recent. Despite the arguments in favor of the use of digital co-creation instruments, the actual implementation and application face several challenges, four of which will be discussed here.

First, there is the challenge of operationalizing the transition process. The transition is a long-term process with open-ended experimentation and complex interactions between subsystems to be transformed. Providing quantitative data and defining meaningful scenarios for analysis with digital city models is challenging, but without this, the tool has limited value. This is reminiscent of the so-called “implementation gap,” i.e., the limited uptake of planning support systems despite their availability (Geertman & Stillwell, 2004, 2009), partly due to limited usefulness for strategic planning (te Brömmelstroet, 2017).

Second, there is the challenge of ensuring that the city transition model is location-specific and up-to-date. Further application is hindered by the substantial differences among cities in their transition challenges, urban subsystems, stakeholders involved, and future city visions. So, there is no one-size-fits-all template for the transition dynamics. Instead, tools, data collected, policy scenarios, and even transition management capabilities need to be tailored to such place-specificities (cf. Larbi et al., 2021). Moreover, the models and underlying data need to be updated frequently to reflect real-world developments. In addition, the city model and simulation scenarios need to be extended for new transition projects when they arise.

Third, planners are dependent on the developers to update the tools and notably underlying models. However, not uncommonly, the development of digital tools is part of academic action research of individual researchers or even research institutes. In fact, researcher-developers may well engage with the stakeholders for the specification of the digital city model and scenarios, participatory design of the interface and the tool’s use cases, and have actual workshops for decision support as the final deliverable of the project. These tools may fail to meet the practical needs of planners. Moreover, for such tools, there is often no explicit intention to develop them commercially or maintain them in the future. Notable exceptions include digital participatory planning systems and laboratories associated with city or regional development institutes. Hereby, a base



platform is developed over time, with smaller tools for specific research purposes built on top. However, since these need to be made location-specific, one faces the second challenge.

Fourth, using digital co-creation tools also requires a change in the role and skills of urban planners. By design, engagement with stakeholders and a focus on mid- to long-term transformation are central. On top of their regular domain knowledge, planners would need to be able to operationally define city development models, specify transition scenarios, develop skills to work with simulation software, and analyze output data. Moreover, effective use of digital tools in planning workshops requires facilitators to make thoughtful interventions to ensure appropriate tool use and balance this with contextual discussions (Pelzer et al., 2015).

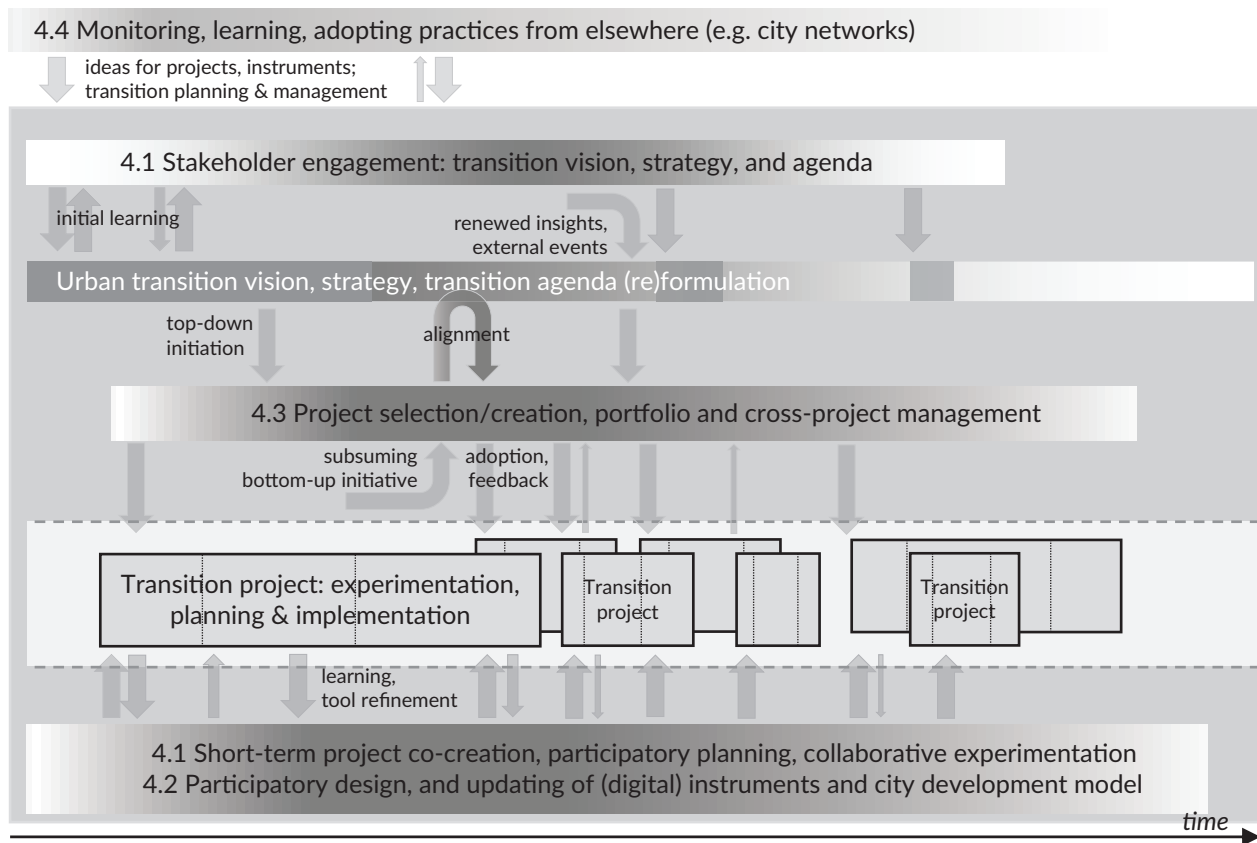
Urban planners face challenges not only in implementing and using these digital instruments, but also in adopting the mindset, procedures, and practices for transition co-creation. This is discussed in more detail in the next section.

## 4. Institutionalization of Co-Creation of the Urban Transition

The urban transition is a long-term process in which a portfolio of relatively short-term projects transforms various urban subsystems. The previous section identified instruments planners may use for the transition planning and management. In line with observations in SSP and, to a lesser extent, UTM, this transition process may also require procedural changes to planning practices. After all, instruments may need to be updated, projects need to be monitored, learning is to be facilitated, and the project portfolio is to be managed. Surprisingly, the literature reports little on the actual institutionalization of such transition planning and management. In fact, while UTM emphasizes that the transition agenda should be anchored, e.g., by engaging and mobilizing stakeholder networks around projects (Roorda et al., 2014; Wittmayer et al., 2018), such durable anchoring is rarely reported (Hölscher, 2018, p. 385). This section discusses four activities of transition management that need to be institutionalized: (a) building capabilities and activities for stakeholder engagement, governance, and co-creation; (b) developing and updating data, tools, and city models for analysis in subsystem transformation projects; (c) building capability for and facilitating learning across projects at the city level; and (d) learning from similar projects as well as transition co-creation methods in other cities. The capabilities and their relationships are depicted in Figure 3 and explained in detail below.

### 4.1. Building Capabilities for Stakeholder Engagement, Governance, and Co-Creation

Both SSP and UTM advocate a change in planning praxis toward engagement with and collaboration between a diverse set of stakeholders far beyond the zoning committee. Given that the urban transition is a unique undertaking for each city, urban planners and the various stakeholders involved will (have to) develop capabilities, both for co-creation of the top-level vision, strategy, and agenda with change agents as well as for subsystem transformation projects (cf. Albrechts, 2013; Frantzeskaki et al., 2018) involving stakeholders closer to the actual construction (e.g., system experts, construction companies, affected citizens, relevant municipal departments). In both approaches, co-creation requires alternative governance structures and long-term commitment, and therefore institutionalization (see e.g., Mahmoud et al., 2021). This shift toward co-creation calls for new skills and education for urban planners (Rooij & Frank, 2016).



**Figure 3.** Schematic overview of capabilities in managing the various urban transition projects. Arrows indicate information flow between different activities for the purpose indicated by the labels. Descriptions are provided in the sections with the given numbers.

Planners must develop capabilities to navigate the different perspectives and interests of the participants, and cope with conflicts and trade-offs by creating effective compromises (cf. Albrechts, 2013).

In SSP, co-creation is to be integrated into the day-to-day planning praxis for both vision formulation as well as proactive co-creation and alignment of real-world transition projects. In this case, co-creation is institutionalized and integrated into urban planning and design, regulations for public utilities, and so on. In UTM, the transition arena is deliberately placed outside of the regular planning institutions (Wolfram, 2018, p. 111). In that case, urban planners need new skills and use new tools in the transition team with a set of *change agents*. Both in UTM and SSP, they need to build governance capabilities used within individual projects (cf. Molenaar et al., 2021). An extensive operationalization of transformative capabilities, notably with regard to governance, engagement, and co-creation, is found in Shahani et al. (2022).

## 4.2. Development, Participatory Design, and Updating of (Digital) Instruments and City Development Model

As seen in Section 3.4, using transition planning instruments has various challenges and requires planning offices to acquire new capabilities. Notably, digital instruments change planning practices substantially (see e.g., Nummi et al., 2023) and planners need new digital skills to use them (Sabri & Witte, 2023). Moreover, these instruments are typically not developed by the municipal planning office, but rather by a software

company and occasionally by an applied research institute. To ensure planners use these instruments (“closing the implementation gap”), they need to be actively involved in their design. Moreover, the actual implementation requires the active contributions of public and private sector stakeholders, decision-makers, and local construction companies in model design to ensure correct representation of urban subsystems and to provide data used in the digital city model. Each transition project in the portfolio (e.g., mobility, energy, waste) requires stakeholder engagement in the formulation of subsystem operationalizations and development scenarios, as well as participatory design of the digital twin or development model, and analysis of experimental or simulation results for decision support. Moreover, external events, renewed insights, as well as the need to analyze previously unforeseen transition projects may call for changes to the digital development model. To remain relevant and useful, the planners need to update the data used and, if necessary, modules in the city development model pertaining to the subsystem transformed. Following such updates, new computational results need to be produced and analyzed. The urban planning office needs to build capabilities for these recurring activities.

#### ***4.3. Building Capabilities for Management of and Learning Across the Portfolio of Transition Projects***

As emphasized, the long-term urban transition comprises an evolving portfolio of relatively short-term projects transforming urban subsystems. Particularly in the SSP line of reasoning, the urban planning office would hold responsibility for managing this portfolio by initiating projects top-down as well as subsuming interesting ones that are initiated bottom-up (e.g., by local communities, non-governmental organizations, or entrepreneurs). The planning office would need to build legal, financial, and organizational capabilities to initiate, adopt, and develop projects, align these projects with the long-term vision, engage stakeholders in practical implementation, and analyze and deal with interactions between projects.

Given the multitude of projects, the focus of learning for planners is not just *within* individual projects but also *across* both different ones in the same city as well as similar ones elsewhere (See Section 4.4). It becomes relevant to adopt and co-develop methods, instruments, and city development models that can be used in the various projects and possibly analyze the interaction of these projects.

In addition, with the substantial chance of both exogenous changes (e.g., regulations or policies at higher spatial scales, changes in national infrastructures) as well as the emergence of unforeseen endogenous challenges, the long-term planning process is generally not linear but rather iterative, requiring revisions and adaptations. Arguably, developments in projects may force planners to revise the vision or the “radical” transition agenda, which in turn may feed-forward in projects.

#### ***4.4. Learning in City Networks at Project Level, Planning Capabilities, and Transition Praxis***

Cities are the niches for experimental urban subsystem transformation (cf. Torrens et al., 2019). Some transition projects may be suitable for small-scale experiments that can be rolled out and scaled up. Other projects require costly, near-irreversible, large-scale implementations that do not allow experimentation. In this case, one could use simulation with digital models, for example. Learning about experiments and projects conducted elsewhere may not only spark ideas for new local projects but also provide clues about effective implementations of experiments or projects readily pursued.

In a network of transition cities (e.g., C40, EU 100 cities, Global Covenant of Mayors), urban planners, change agents, and other stakeholders may learn from processes, experiments, and project results in other cities. Clearly, due to local particularities, “best practices” cannot be directly applied to other cities per se (Bulkeley, 2006), but must be tailored to new conditions. Moreover, apart from learning about ideas, particularities, tools, and methods for individual projects, one may also seek insights into planning capabilities, instrumentation, as well as digital city development models for urban multi-system analysis. Note that information shared in such city networks would allow comparative multi-city studies and thus contribute to the development of methods, learning on the role of local particularities, and ultimately the advancement of urban transition theory (Roorda et al., 2014; Webb et al., 2018; Wittmayer et al., 2016).

## 5. Conclusions and Discussion

Recently, urban transition and planning theory scholars turned their attention to the co-creation of the radical transformation of urban subsystems. However, it is not clear what co-creation is in practice, which instruments exist, and how these instruments can be used effectively. This is partly caused by the ambiguous and rapidly developing conceptions of the urban transition process. Based on SSP and UTM, the urban transition is conceived as a long-term process driven by a co-created vision and agenda with recurring management of an evolving portfolio of relatively short-term co-creation projects to transform urban subsystems (e.g., infrastructures, utilities, services, built environment). This article identifies types of instruments and examines the institutionalization of capabilities for their application and development.

Based on the inventory of instruments, four types are identified (participatory planning and communication, expert planning support systems, urban living labs, and virtual transformation labs) that are particularly suitable either for conceptual exploration or computational analysis, and either for short planning horizons or long-term, iterative co-creation. The co-creation tools and the living labs offer platforms for engagement and vision formulation, whereas the digital tools offer valuable complementary ways to analyze subsystem transformations. Particularly the “virtual transformation lab” is well suited to using city *development* models for strategic decision-making. Given that the three dimensions for classification as well as the clustering of instruments are based on qualitative content analysis rather than theoretical arguments, follow-up research should take a critical look at the typology and instrument classifications.

Given that transition challenges evolve, regular updates to models and data, alignment with planning needs, and continuous stakeholder engagement are essential. In addition, urban transition planners need to engage stakeholders, manage project portfolios, and foster continuous learning within and across projects. This underlines how co-creation with these instruments should be institutionalized within transition planning and management practices. Further case studies are needed to gain insight into the challenges of developing and applying such instruments, as well as building the required capabilities.

The operational and managerial activities thus discerned could be performed by a “Transition Planning Office” (TPO). This TPO could host the capabilities for stakeholder engagement in collaborative planning, participatory design of models, collection of city data, etc. It could manage the portfolio of projects, initiate or subsume projects, provide legal and financial support for individual projects, align projects with the overarching vision or resolve conflicts and exploit synergies between projects. It may deal with uncertainty in strategic planning by making substantive learning within and across projects integral to procedures and the planning mindset.

Moreover, it could build capabilities for all four types of instruments, e.g., contribute to an urban living lab or co-develop a city model for a virtual transformation lab. Additional research is needed to define such a TPO and assess its viability in planning practices. The notion of a TPO extends the conceptual frameworks used. It complements UTM's temporary stand-alone transition arena with active involvement in long-term practical planning and implementation. In addition, it complements SSP's call to make urban planning more strategic by building capabilities for operational planning, managing a portfolio of projects, and developing and using a variety of instruments. Arguably, a limitation of this article is its exclusive focus on SSP and UTM. Further research should explore alternative perspectives on planning (e.g., adaptive urban planning) and urban change (e.g., tactical urbanism), which may offer different conceptions of the transition process, stakeholder participation, or the use of instruments.

Further research is required to examine the place-specificities of transition challenges and the implications for instrumentation and institutionalization. After all, transition challenges and planning practices in megacities differ from those in towns, and those in cities in developing countries differ from those in developed countries (cf. Parnell & Robinson, 2012; Watson, 2016), both in terms of existing and envisioned urban subsystems, infrastructural elements, socio-economic factors, governance capabilities and styles, data acquisition capabilities, and required institutional and instrument developments. In addition, given that urban transition initiatives are embedded in development policies and sustainability initiatives at regional, national, and international levels, greater multilevel alignment may be needed to create a supportive regulatory environment (cf. Bulkeley & Betsill, 2005).

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### Conflict of Interests

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