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The infrastructure transition canvas: A tool for strategic urban infrastructure planning

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ABSTRACT

Increasing pressures resulting from global environmental and societal changes urge cities to adapt their infrastructures. Strategic planning in local governments and utilities has to anticipate these challenges and translate them into innovation and investment strategies. In this setting, a multitude of actors, their interests, and value orientations have to be considered in decision-making. Else, innovation projects are likely to meet resistance and fail. We outline how business model thinking can help navigate the roles and interests of a variety of stakeholders in nature-based infrastructure implementation. This leads to proposing the tool of 'Infrastructure Transition Canvas' (ITC), which draws on insights from business model innovation, and its recent uptake by transition scholars. Potential benefits of applying the ITC are illustrated by the case of urban stormwater management in Germany. We discuss how the ITC may support complex investment decisions, and pave the way to sustainable urban infrastructure transitions.

1. Introduction

The design of urban infrastructures takes on an important role in the mitigation of and adaptation to environmental and societal challenges like climate change, population growth or biodiversity loss. Local governments and utilities in cities therefore have to explore alternative socio-technical configurations to reduce their environmental impact and increase resilience to changing environmental conditions [1]. Nature-based solutions (NBS) have been widely considered to tackle challenges like biodiversity loss, air pollution, heat waves, floods, droughts, as well as resident health, and social issues [2–4]. NBS have been defined as "actions to protect, sustainably manage, and restore natural or modified ecosystems, that address societal challenges effectively and adaptively" [5]. As such, they include, for instance, the planting of urban forests and street trees to adapt to climate change, or urban parks to promote social cohesion [6]. NBS can provide a higher number of multifunctional and cost-effective solutions compared to conventional infrastructure. For example, they can be used simultaneously to drain and store stormwater, treat wastewater, or improve air quality and quality of life [2,7,8].

However, there are high barriers to implementing NBS in today's infrastructures. The underlying policy and governance frameworks for infrastructure planning have historically been optimized for techno-economic performance under rather stable boundary conditions, employing valuation approaches based on cost optimization [9]. Also, for each planning step and for each infrastructure sector, there are clearly predefined roles, and corresponding actors are usually involved at specific stages in the process.

On the other hand, NBS-implementation projects cut across conventional task descriptions of planning or infrastructure entities, and generate multiple values and costs for different government departments and a wide range of external stakeholders. Inter-organizational and cross-sectoral collaboration is one of the key challenges for innovation success [10]. Therefore, already determining who should be the leading actor is often not obviouos. Objectives, responsibilities, and resources of a wide diversity of actors have to be considered and translated into effective decision-making structures at an early stage in the planning process [2,7,11].

To tackle these problems, transition scholars have taken inspiration from the business model literature, which describes how private companies can provide value to customers, while balancing the different costs for providing their services [12]. However, Frantzeskaki et al. (2019) [12] already pointed out the need to extend the business model perspective when planning for public service innovations. The particular

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challenge in infrastructure innovation like in the case of NBS is that instead of a single actor having decision power – e.g. the executive board in a business company – critical resources and competencies are controlled by different actors and solutions have to be accepted by a multitude of stakeholders. In addition, environmental, social, and economic externalities make it very difficult to balance the different costs and benefits for a diversity of actors [12]. Therefore, identifying the relevant actors and specifying their respective roles and responsibilities in the decision process has to be solved before strategies, business plans or even management arrangements can be formulated.

To translate the perspective of a business model from a single decision-maker setting into a multi-stakeholder management structure [10,13], we propose here a new tool, which we denominate as 'Infrastructure Transition Canvas' (ITC). The ITC enables a systematic mapping of the relevant actors in an infrastructure implementation project, their potentially diverging capabilities, values and interests, as well as the specific costs and risks that they will be confronted with. This enables to reflect on the specific roles different actors could take over in the implementation process, as well as potential intermediation tasks or compensation schemes. It draws on and integrates earlier applications of the Business Model Canvas (BMC) by transition scholars [9,14,15] to improve implementation success. This systematic analysis enables the formulation of concrete strategies and business models. In our contribution, we focus especially on local governments and utilities, as these are typically responsible for urban infrastructure projects in the established socio-technical regime in OECD countries.

In the present paper, we will show how the ITC supports answering two main questions: (1) Who are the key actors and stakeholders for implementation of alternative infrastructure solutions using NBS as an example? (2) What roles can these actors assume reflecting on their activities, resources, and prevalent value orientations?

As empirical domain to test and illustrate potential benefits of applying an ITC approach, we will elaborate on the results of its application in urban water management (UWM) projects in Germany. In OECD countries, the dominant UWM regime is characterized by maintaining a rather centralized, linear sequence of processing steps. Sewage and stormwater are collected and transported to a central sewage treatment plant. Historically, the rationale driving these regime structures were hygiene concerns in European cities around the turn of the 20th century [16,17]. More recently, this infrastructure system has been challenged by a number of sustainability concerns [18]. For instance, climate change may lead to an increase in heavy rainfall events, urban heat islands, or droughts that will increasingly affect the well-being of citizens, but also impact the functionality of the current water infrastructure. NBS can make an important contribution to solving these challenges. An example of the numerous benefits that NBS measures such as green roofs and walls, ponds, or waterways can have for UWM is that they may relieve the sewage system from overflow during heavy rainfall events. However up to date, NBS are still far from mainstream [19] because they represent unwieldy and potentially disruptive projects for established planning routines and responsibilities [20]. We will illustrate the advantages and challenges when applying the ITC approach to water-related NBS projects in three German cities: Bremen, Ostfildern, and Bochum.

The paper proceeds as follows: First, we review the strategic infrastructure planning literature in the field of UWM. We then elaborate how transition scholars have drawn on business model innovation concepts to support urban infrastructure transitions. The ITC is then presented as an integrative tool to address appropriate management structures for NBS projects. Section 3 illustrates the empirical and methodological approach to run feasibility tests and to inquire potential benefits of the proposed tool. In section 4, we elaborate on a post-hoc application of the ITC to a project conducted by the city of Bremen and elaborate on potential application profiles of the method across the spectrum of cases of Bremen, Ostfildern and Bochum. In section 5, we discuss how an ITC-informed strategic planning approach may support longer-term sustainability transitions in urban infrastructures and conclude with assessing the potential role of the ITC in an integrated urban planning approach.

2. The challenges of infrastructure innovations

2.1. Conventional strategic planning procedures as innovation barriers

Looming challenges of global environmental and societal change increasingly resonate with visions of local governments and utilities. A plethora of more or less radical technological innovations have been proposed and discussed as a consequence. However, successful implementation is still lagging and more fundamental transitions are still rare [e.g. 21–23]. Planning procedures and management structures are normally optimized for reproducing what transition scholars call "the dominant socio-technical regime", i.e. the strongly aligned rules that guide the actions of different actors in order to maintain established technologies, organizational forms, and performance criteria [24]. This core set of rules is in particular visible in the evaluation methods for technological alternatives, which contribute to strong path-dependencies and a widespread innovation deficit in the sector [20,25–28]. In general, the sustainability goals are still not well reflected in urban planning and policy practices [29].

Strategic planning is the management task where sustainability visions are translated into investment and innovation decisions [30]. Strategic planning has to anticipate future context conditions, balance between corporate and stakeholder interests, and define goals for future operation [31]. However, conventional strategic planning in infrastructure sectors still often refers to existing regime structures and resists radical change [32,33]. It aims at reducing complexity and uncertainty through a "paradigm of linear change", which assumes predictable future states and incremental change continuing on trends of the past [34]. Uncertainty is often reduced by ignoring radical system alternatives and considering a narrow set of (economic) values to compare alternatives [35–37].

In the prevailing regime, conventional planning practices often fail to embrace the whole set of value positions for all relevant stakeholders [36,38,39]. Moreover, current methods for evaluating the broad set of emerging costs and benefits of infrastructure investments often emphasize partial economic returns over social and environmental targets [9]. Consequently, actual planning often faces difficulties in anticipating disruptive dynamics induced by radical technological alternatives [32,37,40,41], and as a result, more sustainable system alternatives often tend to be overlooked in the planning and implementation process [36].

To allow for radical innovation in such complex socio-technical systems, an elaborate and open strategic planning approach is required [38]. On the other hand, strategic planning alone is not sufficient. Implementation may still confront manifold hurdles especially for more radical and disruptive forms of innovation. In order to ensure that strategic planning meets the requirements of sustainable development, we need to embrace radical alternatives more proactively, involve the relevant stakeholders, and assess implementation projects according to broader value concerns than economic performance alone.

2.2. Actor identification and their value positions for nature-based solutions

NBS are multi-functional infrastructures that span across responsibility domains and interests of many different actor groups and require expertise from diverse disciplines for their successful realization. As a consequence, they typically do not fit neatly into established domains of infrastructure planning [10,42]. A lot of recent research has addressed the requirements to successfully implement NBS, which amongst others included discussions on collaborative governance to support NBS implementation [10], planning NBS in cities [1], or

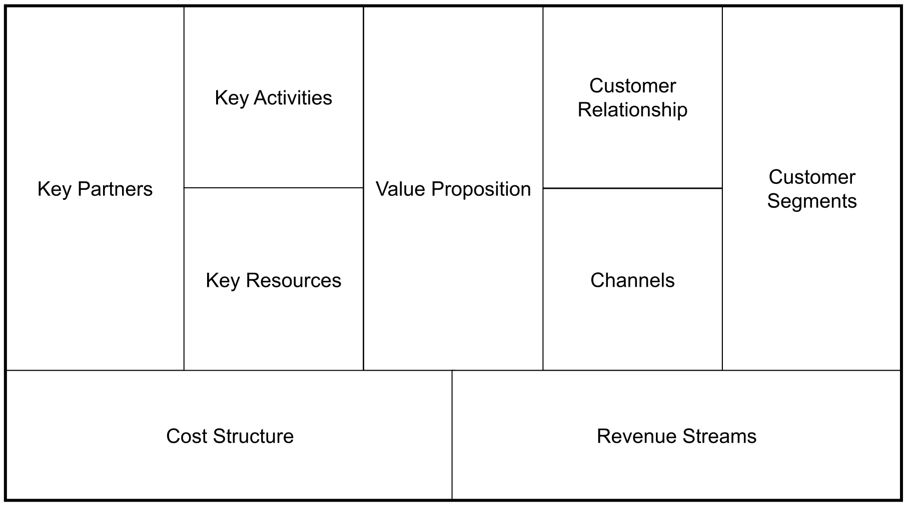

Fig. 1. Business Model Canvas by Osterwalder and Pigneur [46].

assessing the co-benefits of NBS [43]. A key knowledge gap relates to the identification of new finance structures [12,44], which can either be provided by public (so far most often the case), or private investment. Business models are an established form to demonstrate and secure return on investment for private companies. Frantzeskaki et al. (2019) [12] note that in many NBS implementation projects, "a workable business model cannot be selected off the shelf" [12]. Furthermore, business models are not very well suited to coordinate investment decisions by private and public financiers. This is primarily because private companies are predominantly interested in return on investment, while public organizations have to cater for a much broader range of values and costs by different stakeholders [44].

In order to bridge these different rationalities, we have to revisit the initial framing of business model thinking and ask how it could be translated into a multiple-actor, multiple-value context of strategic decision making. In the original management literature, business models have been introduced to coherently connect corporate planning (strategy) with its operative process management (implementation) [45]. One of the core questions is how companies create and capture value for themselves, their customers, and suppliers [46–49]. A widely adopted tool for representing the elements of a business model is the Business Model Canvas (BMC) of Osterwalder and Pigneur [46]. The BMC can be described as a visual representation of how an organization creates and captures values [49,50]. It is subdivided into nine 'building blocks' (see Fig. 1), which contain the 'value proposition' at the center of the canvas, describing the key offering of the focal firm to different customer segments. These offerings can be provided by drawing on 'key resources', 'key activities', and 'key partners'. The customers are divided into 'customer segments' to which the offering should appeal, 'customer relationship' specifying the connection between the focal firm and the customer segments, and finally the 'channels' through which the company communicates with its customers. On the other side, the BMC depicts the financial flows generated by the 'cost structure' and the 'revenue streams' [46].

In order to translate the value creation process to multiple-actor, multiple-value contexts, a number of extensions have recently been proposed by transition scholars. For instance, Bocken et al. [14] aimed at addressing value propositions to a broader range of stakeholders by elaborating a "value mapping tool for sustainable business modelling". Foxon et al. [9] linked business model thinking with urban infrastructure transitions for sustainable infrastructure investment. The authors have explicitly considered social and environmental "value propositions" and "value streams", which are essential for the provision of public services. Interactions between different actors were addressed by a number of studies, e.g. by Rohrbeck et al. [51] and Breuer and Freund [15]. Rohrbeck et al. [51] argued that sustainable innovations are systemic in nature and therefore require coordinated action by multiple organizations. The authors focus on how mixed private and public actor networks may develop "collaborative business modelling" to foster sustainable innovations in the smart-grid sector. Breuer and Freund [15] introduced the concept of "values-based networks", to help organizations identify shared values among each other in order to solve societal problems. Van Rijnsoever and Leendertse [52] proposed a Transition Model Canvas (TMC), which aims at supporting collaborations between scholars and transition practitioners to enable socio-technical transitions.

These extended approaches provide important inroads on how infrastructure planning can be supported by an extended business model approach. However so far, their proposed conceptualizations focus on different challenges, which overlap only partially. An integrated perspective is still lacking. Furthermore, all perspectives assume that a clearly defined leading actor has to coordinate the innovation process. They are less suitable to address situations where actor constellations and leadership positions are still open and where value positions of diverse stakeholders have to be negotiated for successful interventions.

2.3. The infrastructure transition canvas

Based on this analysis, we propose a key element for an integrated transition planning approach that is inspired by business model thinking: The Infrastructure Transition Canvas (ITC). A core problem of translating the single company planning approach towards a planning task in multiple-actor, multiple-value contexts resides in the appropriate identification of the range of actors, their diverging value orientations and the resulting costs and benefits that alternative infrastructure designs will imply for them. As opportunities for value creation, capturing, or even destruction, are often unevenly distributed among relevant actors, power relations have to be taken into account, as well. Otherwise, the corresponding projects will lack legitimacy, will be fought against or will just shift externalities from one actor group to another. The ITC will therefore depict how the roles of actors and resulting governance arrangements should be conceived during the planning process, but also in the later implementation and operation of the new infrastructures.

The ITC is essentially constructed as an extension of the classical BMC in the interest to capture the additional challenges that need to be addressed in more complex decision situation. For this purpose, the depiction of 'key actors' in the BMC has to be extended to a wider range of stakeholders contributing to the implementation of an infrastructure project first. Second, the BMC 'customers', have to include all ways relevant stakeholders can affect or how they will be affected by the

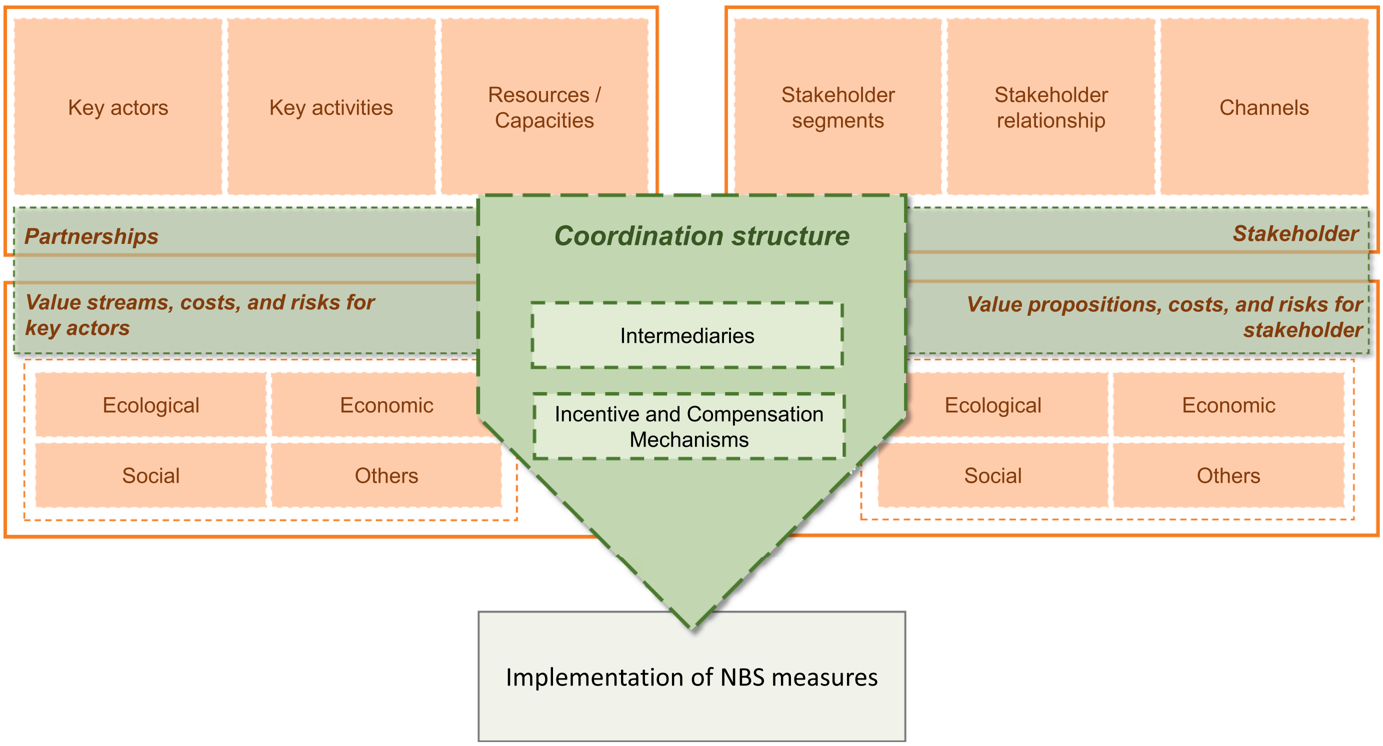

Fig. 2. The Infrastructure Transition Canvas for strategic planning of urban infrastructure, e.g. to integrate NBS measures —— Layer 1 (orange) - Actor- and value-based components; —— Layer 2 (green) - Coordination structure.

project. Third, these actors have to be specified in terms of the values, costs, and risks they will have to confront when the project is implemented. While these three adaptations represent rather straight forward extension, the requirement of a distributed decision-making situation implies an additional layer of coordination compared to the situation of a business company: the installment of intermediary actors and devising of incentives and compensation mechanisms.

We may therefore represent the ITC as depicted in Fig. 2. When applying the ITC, the elements of the orange layer have to be compiled first. In a second step, the relationships between the key actors and stakeholders (orange layer - upper part) are examined and suitable governance structures are chosen (green layer - intermediaries). The mapping of the different values, costs, and risks (orange layer - lower part) may reveal an uneven distribution of value considerations among the key actors and stakeholders, which can be addressed by developing appropriate incentive and compensation mechanisms (green layer).

2.3.1. Actors and stakeholders

The partnership box encompasses all actors that are proactively contributing to the value creation process (key actors) and those that will be impacted by the project without having an active say (stakeholders). Key activities and key resources comprise the most important set of actions and assets that are required to implement the project successfully. Key resources contain material and immaterial means of provision (physical, intellectual, human, or financial). On the stakeholder side, 'segments' refers to different types of impacted actors, 'relationships' relates to how they are impacted by the project and 'channels' identifies whether and how interaction with the different segment would have to be organized, for instance in the form of municipal council meetings, information campaigns on technological innovations, citizen participation procedures, or expert consultations.

The original BMC considers customers as the main stakeholders, as they generate the cash flow for the focal firm. The extended BMC for infrastructure [9] additionally considers infrastructure users as key stakeholders. The value mapping tool [14], collaborative business modelling [51], and the values-based network [15] consider all kinds of relevant stakeholders instead of customers and users only. These stakeholders include also such abstract entities like 'the environment' and 'society'. Following this suggestion, the ITC conceptualizes 'stakeholders' as all actors that affect or are affected by an intervention [53], including the environment and society.

2.3.2. Costs, risks and benefits for key actors and stakeholders

The lower part of the ITC in the orange layer in Fig. 2 displays the value-based elements. They comprise the benefits, costs, and risks that accrue to the key actors and stakeholders through the project. These elements differ strongly from the original BMC, which are limited to the key 'value proposition' to the customers, and the 'revenue stream' and 'cost structure' for the focal company. In a multiple-actor, multiple-value context, we follow Bocken et al. [14], Rohrbeck et al. [51], Foxon et al. [9], and Breuer and Freund [15] and include social and ecological values besides the economic value. Depending on the infrastructure sector and the concrete intervention, further criteria could become relevant that we summarize as 'others'. For example in urban water management, very high hygienic and safety standards need to be either reached or even surpassed in OECD countries. For instance, Sartorius et al. [54] suggest to supplement the sustainability criteria, i.e. ecological, economic, and social, by further 'safety-relevant' and 'technical' criteria, or 'design', especially in cases where infrastructure is built above-ground instead of under-ground. We differentiate between 'value streams' for key actors (including the revenue stream) and 'value propositions' for different stakeholder segments, including positive externalities [14]. Finally, the ITC captures the main costs, risks and negative externalities that the actors and stakeholders have to accommodate with.

2.3.3. Actor coordination and governance structures

A main implication of multiple-actor, multiple-value contexts is that no single actor has the power and capacity to balance the different trade-offs [55]. The green layer therefore describes the different coordination structures that are needed to achieve this task. It indicates the need for solving leadership questions in cases of unclear or conflicting responsibilities among government departments, for instance, and how to accommodate for unbalanced cost-benefit tradeoffs for specific actors and stakeholders.

In complex decision contexts, leadership tasks are often delegated to "intermediaries", especially in urban infrastructure transitions [39,56]. Guy [56] outlines that intermediaries can be very different forms of actors, e.g. individuals, organizations or networks of organizations, institutions, processes, or even technologies. Kivimaa et al. [57] define intermediaries for sustainability transitions as "actors and platforms that positively influence sustainability transition processes by linking actors and activities, and their related skills and resources, or by connecting transition visions and demands of networks of actors with existing regimes in order to create momentum for socio-technical system change, to create new collaborations within and across niche technologies, ideas and markets, and to disrupt dominant unsustainable socio-technical configurations" [57]. Intermediaries in that sense have the potential to mediate between key actors and stakeholders identified in the orange layer.

Incentive and compensation mechanisms, on the other hand, comprise measures that aim at balancing an unequal distribution of values, costs, and risks among different key actors and stakeholders. These considerations can be a starting point for designing new business models [see e.g. 15] and adequate return on investment, e.g. in public-private partnerships. Examples could be financial compensation payments for actors who bear particularly high costs without receiving an adequate benefit, or tax incentives to operate or maintain new infrastructures. The ITC enables the identification of challenges in the cost and benefit relations of diverse actors. The actual design of compensation mechanisms is however beyond the reach of what the tool can accomplish. These will have to be elaborated based on insights from disciplines like institutional economics, management studies, administrative sciences, or even psychology and communication.

In conclusion, the ITC approach enables a systematic mapping of the multiple-actor, multiple-value context, which characterizes most infrastructure innovation problems, and in particular NBS projects. It can serve as a basis for negotiation and communication between the parties involved to better understand their respective roles at the beginning and during the process. Of course, the systematic mapping may lead to extremely busy and complex data collections and the graphic representation might quickly become overwhelming. In the following, we will therefore illustrate how this approach may actually support decision-making in infrastructure projects and where the specific benefits are, but also where the method hits its limits. We see its use especially in early phases of project formulation, in the sense of a systematic stakeholder analysis and an anticipation of potential conflicts and needs for intermediation. It could however also be applied post-hoc to better understand why a project encountered problems and oppositions as well as whether and how they could have been identified and prevented beforehand. In conceptual terms, we claim that we complement and integrate earlier approaches to an extended application of the business model perspective on multiple-actor, multiple-value decision contexts.

3. Method and case selection

The ITC was tailored to meet the needs of strategic infrastructure planning, using the BMC from the business management literature as a basis. In a first step, we designed the ITC prototype on conceptual grounds. This was mainly based on literature on strategic planning and the requirements for NBS implementation. To further improve the design of the tool and to formulate expectations about its performance, we discussed the ITC prototype and the operationalization of the different components jointly with nine experts from academia, policy making, public administration, and industry in the urban water sector. In a third step, we tested the ITC post-hoc in three extended German NBS cases in Bremen, Ostfildern, and Bochum by means of expert interviews and workshops and compared the results with regard to the potential added value that applying the ITC would have had (see Section 4.3).

In Germany, urban water management is divided into water supply management and wastewater (= sewage and stormwater) management. Sewage and stormwater are mainly collected and transported in a mixed or separated channel to a central sewage treatment plant. In our test cases, we focus on situations where stormwater management is impacted by heavy rainfall or droughts, or confronted with high construction or maintenance costs for the conventional (grey) infrastructure. All three cases propose specific forms of NBS. The cases are characterized by multiple-actor, multiple-value contexts, but had different levels of impact and project scopes - city-wide strategy in Bremen, district-wide implementation in a new district in Ostfildern, and local implementation in an existing road section in Bochum - and different extends of value conflicts between the involved actors. The projects also differ in their duration (approx. 2 years in Bremen, approx. 20 years in Ostfildern, and approx. 3 years in Bochum).

In Bremen, the municipal authority for environmental affairs established a multi-stakeholder strategy process for a better adaptation to extreme rainfall events in 2014. One important sub-part was water and climate sensitive urban development, for which NBS represent innovative but also disruptive measures for urban water management. We conducted six semi-structured interviews with experts in the municipal authority for environmental affairs and experts from a first pilot project at the new Hulsberg district.

In Ostfildern, surface drainage was installed in a new suburb in 1991, e.g. in the form of green roofs or shallow grass swales. As a consequence, a part of the rainwater is now retained at the point of origin. The installed NBS measures significantly relieve the pressure on the wastewater treatment system in Ostfildern. We conducted four interviews with the responsible experts in the department for urban planning, the civil engineering department, the project manager, and an expert for landscape architecture and urban planning that have initiated the implementation of the surface drainage.

In Bochum, the civil engineering department implemented NBS measures in the form of interconnected tree trenches on an already existing road section in 2021. We applied the ITC in an online workshop and afterwards conducted supplementary expert interviews. The expert workshop was attended by representatives from the responsible civil engineering department for UWM and the department for the environment and green spaces. Unfortunately, we could not integrate the perspective of the department of road constructions, as department representatives cancelled their participation in the workshop and did not respond to the interview request. We interviewed five experts, three working for the civil engineering department, the head of the mayor's staff unit for climate and environment, and an expert of the Water Management Association in the river Emscher region.

By applying the ITC to the test cases, we examined the extent to which the ITC is able to reveal the relevant key actors and stakeholders and associated value considerations. Furthermore, we aimed to explore the advantages and limitations of the tool in realistic application contexts. As an example of the ITC application outcome, we present the Bremen case in detail in the Sections 4.1 and 4.2. In the interviews and workshop, we discussed the elements of the ITC and asked about potential benefits and limitations of the proposed tool. The resulting data from the expert interviews and workshop were supplemented with publicly available information on benefits, costs, and risks associated with NBS measures in general.

4. Application and illustration of the ITC

In the Bremen case, we collected and mapped the elements that are relevant for strategy implementation by applying the ITC (for a detailed ITC mapping of all elements, see Appendix Fig. A1). In the following Sections 4.1 and 4.2, we provide a general overview of these elements.

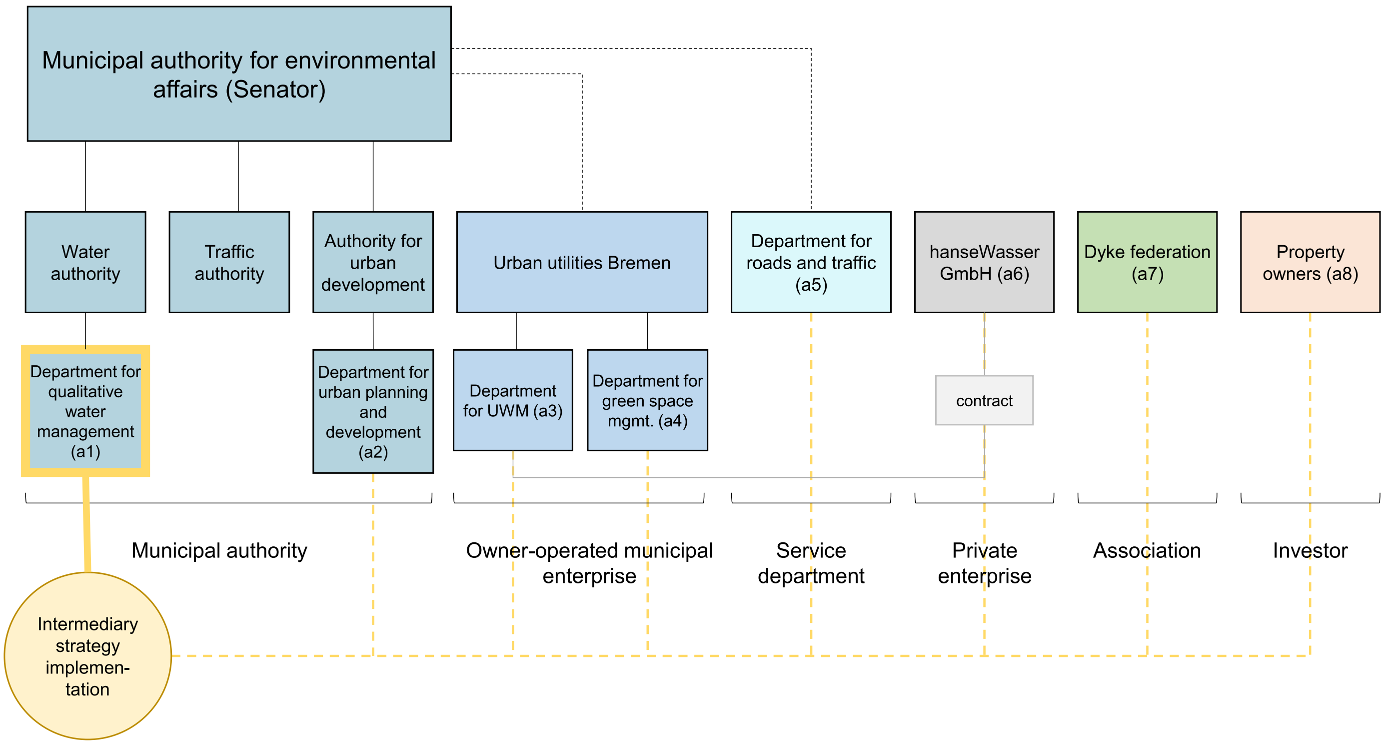

Fig. 3. Organizational chart of the key actors for water and climate sensitive urban development in Bremen (the intermediary actor of the strategy implementation phase, the department for qualitative water management, is put in a yellow frame).

4.1. Multiple actors and multiple values as key ITC components in Bremen

We identified eight key actors that, according to the consulted experts, need to be considered in the strategy implementation process. We attributed the key actors with the codes (a1) - (a8). These are the department for qualitative water management (a1) and the department for urban planning and development (a2), both located at the municipal authority for environmental affairs; the department for urban water management (a3) and the department for green space management (a4), both part of Bremen's urban utilities; the department for roads and traffic (a5), which is a service department for the municipal authority for environmental affairs; the hanseWasser GmbH (a6), a private enterprise that provides water-related services for the city's utility; the Dyke federation (a7) as association for flood protection; and finally the property owners (a8) as investors. Fig. 3 schematically shows the organizational positioning of these key actors.

For the strategy implementation process, the department for qualitative water management (a1) took on the leading role. In cooperation with the department for urban planning and development (a2), the main task of (a1) was to adapt the informal and formal planning processes to the new requirements of water and climate sensitive urban development. Besides, (a1) was identified as regime-based transition intermediary that is "tied […] to the prevailing socio-technical regime but has a specific mandate or goal to promote transition and, thus, interacts (often) with a range of niches or the whole system" [57]. The intermediary role of (a1) is especially relevant as the integration of NBS for a water and climate sensitive urban development is likely to change actor roles and power constellations.

In the interviews, (a1) stressed the importance of communicating the corresponding roles of the relevant actors in the transition process. For example, the urban utility / department for UWM (a3) and the hanseWasser GmbH (a6) were so far responsible for wastewater disposal in Bremen. The interviews showed that these key actors will also be important for water and climate sensitive urban development. However, in the context of NBS projects, they may not necessarily be in the lead anymore. NBS include a broad set of potential measures for water and climate sensitive urban development. In many of these measures, water is not discharged directly underground, but is used e.g. on the surface to irrigate green spaces and trees or to improve evaporation and cooling. This can result in new responsibilities and roles for different actors, depending on the specific NBS measure. The ITC can help identifying these new roles and responsibilities with the associated key resources, key activities, value streams, costs and risks. In Table 1, we provide an overview of identified potential new leading actors for NBS implementation projects and their associated new roles (for details, see Appendix Fig. A1).

Table 1
Potential leading actors and their associated roles for NBS implementation projects in urban water management.

Potential leading actors for NBS implementation projects	New role of the actors
Department for urban planning and development (a2)	Implementing NBS measures when designed as central elements throughout the city or in parts of the city, such as interconnected green and blue areas
Department for green space management (a4)	Implementing NBS in the form of urban greenery and parks Implementing NBS in the form of roadside greenery
Department for roads and traffic (a5)	Implementing NBS in the form of roadside greenery
Dyke federation (a7)	Integration of NBS measures to fulfill its mission and objectives, for example, to prevent coastal flooding
Private actors, e.g. property owners (a8)	Installing and maintaining green spaces, green roofs or green walls on their properties

Water and climate sensitive urban development can have various potential value streams for the department for qualitative water management (a1), the department for urban planning and development (a2), the department for urban water management (a3), and property owners

Table 2
Potential value streams, costs, and risks for key actors; (+) potential value streams, (-) potential costs and risks.

Key actors	Potential value streams, costs, and risks
Department for qualitative water management (a1)	(+) Sustainable urban development: inclusion of various hazards regarding heavy rainfall events and their mitigation
Department for urban planning and development (a2)	(+) Sustainable urban development: inclusion of various hazards regarding heavy rainfall events and their mitigation (+) Attractive urban space design
Department for urban water management (a3)	(+) Relief of sewage network during heavy rainfall events
Department for green space management (a4)	(+) Availability of irrigation water for plants (-) Costs in planning, implementation, and long-term operation
Department for roads and traffic (a5)	(-) Costs in planning, implementation, and long-term operation
Property owners (a8)	(+) Higher resilience towards heavy rainfall events (+) Attractive urban space design (+) Financial advantages (+) Unique selling propositions as "eco-friendly"

Table 3
Potential value propositions, costs, and risks for stakeholders; (+) potential value propositions, (-) potential costs and risks.

Stakeholders	Potential value propositions, costs, and risks
Politicians (s1)	(+) Solutions to counteracting climate change impacts that generally have majority appeal (-) Risk of missing political support from the society
Municipal authority for economic affairs (s2)	(+) Higher resilience towards heavy rainfall events and resulting risks (-) Risk of higher costs for housing (especially in the short-term)
Citizens / citizen initiatives (s3)	(+) Higher resilience towards heavy rainfall events and resulting risks
The environment (s4)	(+) Environmental protection + ecological enhancement
Housing companies (s5)	(+) Financial advantages (-) Risk of higher maintenance efforts for measures of water and climate sensitive urban development
Future inhabitants (s6)	(+) Financial advantages (-) Risk of higher maintenance efforts for measures of water and climate sensitive urban development

(a8). For the department for green space management (a4) and the department for roads and traffic (a5), however, the realization of NBS primarily incur costs in planning, implementation, and long-term operation that are not yet covered by the existing municipal budget. For these key actors, benefits offsetting these costs, for example the availability of irrigation water for plants (a4), could prove too insignificant to participate in NBS projects or even take over a leading position. Therefore, new incentive and compensation structures would have to be defined to support project success (see Section 4.2).

In Table 2, we provide a selection of potential value streams, costs, and risks for the key actors related to NBS that can be unevenly distributed among these actors (for details, see Appendix Fig. A1).

We learned that stakeholders can have a major influence on the successful implementation of NBS measures and that stakeholders' perspectives and requirements can be extremely diverse, which puts stakeholder identification and management in a central position for successful NBS project implementation. Through the ITC, their positions can be identified at an early stage and tensions can be recognized. In Table 3, we provide a selection of potential value propositions, costs, and risks for the stakeholders related to NBS (for details, see Appendix Fig. A1).

In the Bremen project, we identified six stakeholders for the strategy implementation process, which we attributed with the codes (s1) - (s6). These stakeholders are politicians (s1), the municipal authority for economic affairs (s2), citizens (s3), the environment (s4), housing companies (s5), and future inhabitants (s6).

Water and climate sensitive urban development might be particularly beneficial for diverse stakeholders such as politicians (s1), the municipal authority for economic affairs (s2), citizens (s3), and housing companies (s5). On the other hand, the risks of rising additional operation and maintenance costs that housing companies would have to cover (e.g. in terms of providing land resources for NBS or the maintenance thereof) (s5) and a resulting increase in housing prices for future inhabitants (s6) can potentially be a major barrier to the implementation of NBS, especially in municipalities where property values and rents are already exorbitantly high. This could lead to a decline of political support for these measures (s1), and lead to resistance by the municipal authority for economic affairs (s2), citizens (s3), and housing companies (s5).

So far, we have shown that a water and climate sensitive urban development is likely to challenge the roles and value considerations of different key actors and stakeholders. As project success depends on the proactive support of the key actors, and passive support of the stakeholders, involvement into the strategy implementation process is key. The identified key actors can either take a leadership role, or contribute to planning, implementation, and/or long-term operation of these new infrastructures. The ITC enables to systematically identify the project specific key actors and their corresponding roles. With regard to stakeholders, possible resistance and support can be anticipated at an early stage. On the basis of this information, it is now possible to derive intermediaries, incentive and compensation measures, and to integrate the relevant stakeholders into the process via suitable communication channels.

4.2. Coordination structure for NBS in Bremen

Infrastructure adaptation to global environmental and societal change is a joint task of diverse actors, e.g. departments of urban and infrastructure planning, utilities, and private actors. However, it often remains unclear who takes the lead in concrete implementation projects.

The leading actors for wastewater management in Bremen are so far the urban utility / department for UWM (a3) and the hanseWasser GmbH (a6). With a potential change in the (leading) roles, new management structures and decision-making procedures would be required involving the identified new actors. Also, new incentive structures and compensation mechanisms would be needed to redistribute costs and benefits. For the case of Bremen, this could be exemplified as follows:

The current intermediary of the strategy implementation phase in Bremen, the department for qualitative water management (a1), was authorized to coordinate water and climate sensitive urban development in the planning process. The department took the lead in connecting the relevant key actors and stakeholders for concrete interventions, e.g. NBS measures. We categorize (a1) as regime-based transition intermediary following Kivimaa et al. [57].

Bremen's pilot project for water and climate sensitive urban development (Hulsberg Viertel) revealed that the actors related to implementation seemed strongly attached to the existing socio-technical regime. In this regard, we identified a gap between strategic planning on city-level and the implementation of concrete NBS measures in the district. In this direction, one of the consulted experts suggested to establish a process intermediary that facilitates NBS implementation projects without explicit individual agency [57].

Concerning incentive and compensation mechanisms, an example we discussed in the interviews concerned appropriate financial arrangements for relevant key actors to ensure the implementation of NBS measures. For example, when stormwater is disconnected from the sewage system through NBS measures, key actors such as the department for green space management (a4) or private property owners (a8) would have to be compensated for taking over additional responsibilities

Table 4
Key features of the examined projects and expected benefits of the ITC.

Key features of the project	Bremen	Ostfildern	Bochum	Expected benefits of ITC
Level of impact / project scope	City-wide infrastructure strategy; sub-area of overall strategy process, i.e. strategy implementation for NBS measures	Precinct infrastructure planning and delivery; implementation of NBS measures in a new district	Local infrastructure planning and delivery; implementation of NBS measures on existing road section	The more specific & clearly defined a project scope is, e.g. a concrete sub-area of strategy development, or specific projects for infrastructure delivery, the more tangible the ITC application outcome is. In the case of very fragmented impact levels, there is a risk of too excessive complexity and overload for the application of the tool.
Extent of value conflicts between relevant actors / stakeholders	Same goals of the involved parties of the strategy development process, but tensions between city-wide strategy and strategy implementation on district level	Few conflicts due to small municipality and close relationships between relevant actors	Major conflicts, as important actors were not involved at project start	ITC helps to identify potential sources of value conflicts and serves as basis for conflict detection and resolution. Increasing complexity of value conflicts reduces the benefits of the ITC.
Duration	~ 2 year	~ 20 years	~ 3 years	Application of ITC at different process steps possible to determine changes in actor constellations or value considerations, most important at the beginning of projects.

and services. An appropriate solution could be to share the rainwater fee among these actors.

By using the ITC, we could reveal risks of higher costs for housing, and of higher maintenance efforts for the municipal authority for economic affairs (s2), housing companies (s5), and future inhabitants (s6). In these cases, it is important to seek appropriate measures that can provide relief in the event of costs (or damages), such as suitable insurance models.

These potential coordination mechanisms only serve as illustrative examples. Establishing appropriate intermediaries, designing a fully integrated set of incentive and compensation mechanisms, and regulatory instruments to promote NBS is complex and needs to be tailored to the specific context and requirements. The ITC is not able to offer specific solutions to these problems, but it indicates who will bear what costs and risks, and what values will be created for whom. Negotiations among actors and insights from diverse social science disciplines might generate solutions for these open questions.

4.3. Added value and limitations of the ITC

In order to further specify potential added values of the ITC, we will now compare experiences from the three cases in Bremen, Ostfildern, and Bochum. The application of the ITC revealed three key dimensions along which projects may differ with regard to the potential benefit of applying the ITC (see Table 4). These are (1) the level at which a project has an impact, from local to global, and the size and extent of a project; (2) the extent of value conflicts among the parties involved; and (3) the duration of a project.

We found that the more targeted and precise the impact level, the more tangible and manageable is the outcome of an ITC application. In Bremen, for example, one expert said the application of the tool might have been beneficial for parts of the strategy process, in this case water and climate sensitive urban design, but not for the overall strategy process. The complexity of the entire process would have been too high to be depicted by the tool. At the level of the sub-process, it could however provide considerable added value, as the tool is able to inform the key actors and stakeholders about their potential roles in the project and where their value and negotiating position lie. We could observe the same in the Ostfildern case: the application of the tool would not have been useful at the level of the entire district planning, infrastructure implementation, and long-term operation, but can be supportive for individual parts of the process, e.g. the implementation of NBS measures. The Bochum case was already compact enough for the ITC to be applicable. In general, the ITC can be used for projects on strategic (Bremen) and operational level (Ostfildern, Bochum).

The comparison between the three cases also proved that the application potential of the tool does not depend on the number of actors and stakeholders involved in a project. What is more decisive is the kind and the extent of value conflicts. In the interviews, we found that the ITC is capable of identifying/anticipating conflicts between actors in order to elaborate on concrete incentive and compensation mechanisms. However, in general ethical discussions, e.g. debates on social justice, the use of ITC is very limited. In these cases, other tools and approaches might be more appropriate [e.g. 58].

We have found that the duration of the projects themselves is also not decisive for the ITC application. What is more important is the timing and frequency of its application. The experts in all cases agreed that the tool might show most benefits at the beginning of a process or project or then at defined milestones of a project to check for changes in actor constellations and value considerations. And finally, it is also possible to use the tool for project evaluation at the end.

The experts consulted stated that they had already implicitly considered most of the elements of the ITC when embarking in the actual planning process. The ITC, however, enabled the systematically mapping of all elements and their interrelationship. As a consequence, the interviewees expect key actors and stakeholders to better understand, communicate, and negotiate their roles at the beginning and during the process. Furthermore, the ITC can help project leaders and participants to understand, which actors and stakeholders need to be considered for project success. In Bochum, for example, the non-inclusion of a key actor resulted in the project running considerably longer than initially planned.

The revealed elements can inform appropriate governance arrangements, business plans or management agreements. The major limitation of the ITC is its rather high level of abstraction and the additional time and resources required for its application.

5. Conclusion

Transitioning urban infrastructure to more resilient and sustainable forms is a complex undertaking that typically involves and affects a wide range of stakeholders who hold different value positions and bear different burdens in the process. With the ITC, we provide a tool for performing a first stakeholder screening and analysis as well as a mapping of emerging values and costs related to urban infrastructure innovation projects. Based on this analysis, the ITC serves as basis to determine roles and intermediation tasks of the identified actors, to negotiate compensation schemes, and create a basis to coordinate investment decisions in a multiple-actor, multiple-value context.

The ITC complements and integrates earlier approaches of the business model perspective into an integrated approach to structure multiple-actor, multiple-value decision contexts. It provides an

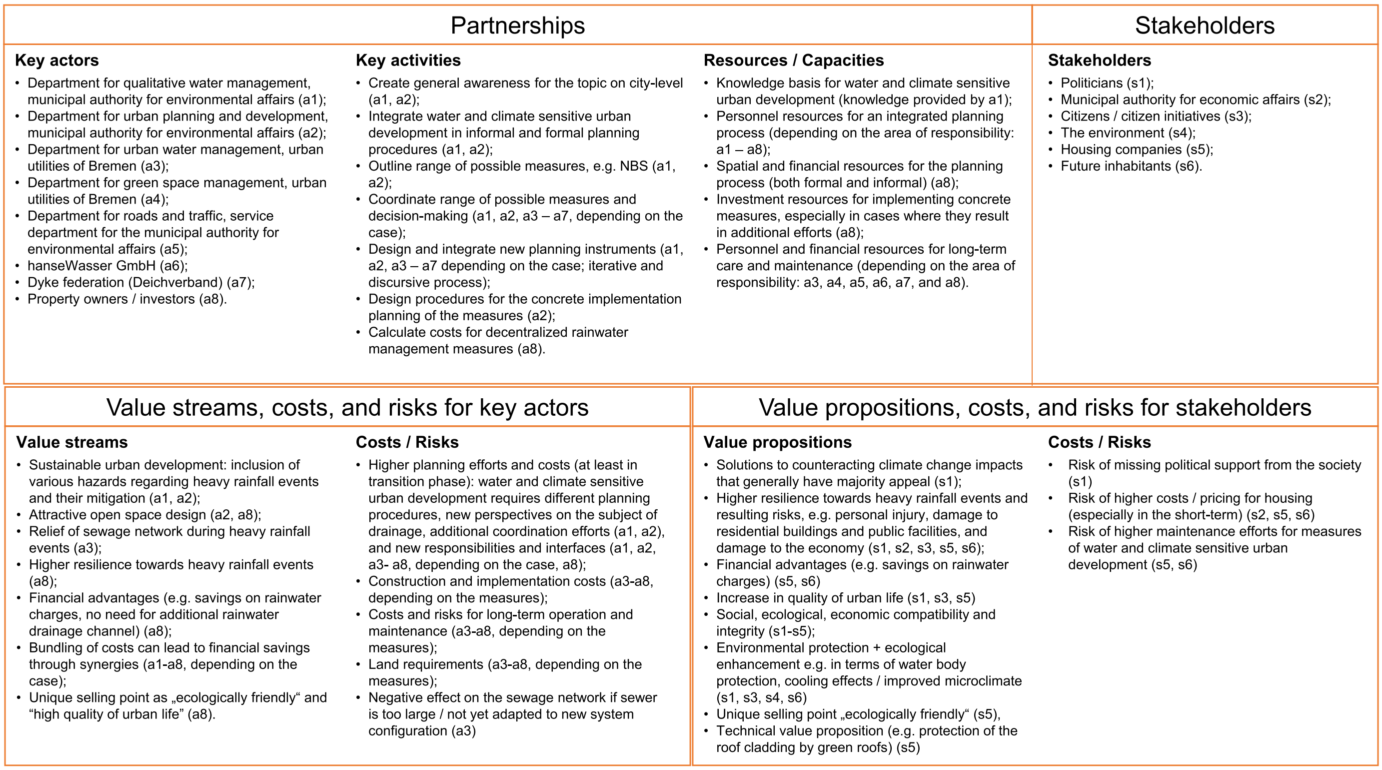

Fig. A1. The Infrastructure Transition Canvas for the integration of water and climate sensitive urban development in the city of Bremen.

important contribution to the multiple dimensions of urban infrastructure transitions. With the support of the ITC, the implementation of infrastructure innovations, e.g., NBS, can be substantiated by first conducting a stakeholder and value mapping and then deriving coordination mechanisms. However, it does not suggest any specific form of impact assessments. The tool serves in particular as a basis for negotiation and communication between the relevant parties. Based on the ITC mapping, decisions can be made about governance structures, forms of collaboration, and actor roles at the multiple-actor level. Zooming in to the level of identified individual actors subsequently enables decisions to be made about specific investments or business models [e.g. 9,15]. The tool can complement extensive approaches such as 'transition management' [59,60].

In this paper, we tested the applicability and relevance of the ITC to inform strategic planning and implementation in the realm of water and climate sensitive urban development, drawing on expert interviews in Bremen, Ostfildern, and Bochum. However, we anticipate that the ITC can be applied to many other urban infrastructure transition problems in multiple-actor, multiple-value contexts. Since the ITC itself is not able to map the power relations between the various key actors, we recommend further research to include such factors in the analysis. Another interesting research direction would be to compare the benefits of ITC at different impact levels, e.g., local, district, city, region, country, or even international level, or to apply the ITC in different geographic or sectoral contexts to explore its application scope. Further research is necessary on how project roles (e.g., intermediaries, leadership) can be designed to make projects successful, how incentives and compensation mechanisms can be developed, or how new governance modes or business models can be designed. Another relevant research direction is to examine the extent to which individual projects can contribute to the transition of the whole sector. The ITC itself can only provide a building block in a more encompassing strategy.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

The authors do not have permission to share data.

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Appendix

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