Impacts of urban real-world labs

Insights from a co-evaluation process informed by structuration theory in Wuppertal-Mirke

To address the evaluation of the societal impact of real-world labs, we present a framework developed for the analysis of structure-agency dynamics: structuration theory. Using this tool on a neighbourhood level, we assess the outcomes of six projects on co-productive city-making.

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Abstract
Ways of evaluating the societal impact of real-world labs as a transdisciplinary and transformative research format are under discussion. We present an evaluation approach rooted in structuration theory, with a focus on structure-agency dynamics at the science-society interface. We applied the theory with its four modalities (interpretation schemes, norms, allocative and authoritative resources) to the case of the Mirke neighbourhood in Wuppertal, Germany. Six projects promoted the capacity for co-productive city-making. The effects of the projects were jointly analysed in a co-evaluation process. Previously proposed subcategories of the modalities as an empirical operationalisation were tested and confirmed as being applicable. Five new subcategories were generated. The use of the modalities seems appropriate for co-evaluation processes. The tool is practical, focused on real-world effects, and suitable for trans-disciplinary interpretation processes. We encourage further empirical testing of the tool, as well as development of the subcategories.

Keywords
co-production, evaluation, real-world laboratory, societal impact, structuration theory, transdisciplinarity, transformative research

Real-world labs (RwLs) belong to a family of transdisciplinary and transformative research (TDTR) formats, which centres around real-world experimentation with the aim to instigate societal learning processes and to foster sustainable development (Caniglia et al. 2020, McCrory et al. 2020, Schäpke et al. 2018, Wanner et al. 2018). Due to the transformative ambitions of such formats, it is essential to evaluate their targeted societal effects. Previous research has contributed with helpful evaluation frameworks for TDTR formats. One group of frameworks aims at tracing, linking, and attributing actions carried out to specific effects, and their contribution to the desired change (Belcher et al. 2019, Belcher and Halliwell 2021, Wiek et al. 2014, Luederitz et al. 2017, Schäfer et al. 2021). Their guidelines and checklists are derived inductively through literature reviews and empiricism. An alternative group of frameworks puts greater emphasis on qualitatively explaining the mechanisms of change and assessing the impacts of real-world experimentation against the background of theories on social change and transformation (e.g., focusing on institutional logics, institutional work, socio-spatial or structure-agency dynamics; Fuenfschilling and Truffer 2014, Augenstein et al. 2022, Bögel et al. 2022, von Wirth et al. 2019). In addition, Williams and Robinson (2020) propose a framework which tries to link both strands by providing a detailed evaluation checklist and using the development pathways approach (which is clearly rooted in social change theory).

Similarly, our intention was to develop an approach that would focus on structure-agency dynamics to analyse transformative

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TABLE 1: Proposed subcategories of the modalities of structuration for urban real-world laboratories, by Schneidewind et al. (2018, p. 15).

INTERPRETATIVE SCHEMES	NORMS	ALLOCATIVE RESOURCES	AUTHORITATIVE RESOURCES
■ shared notions/terms ■ shared narratives ■ local identity	■ rules of legitimised interventions ■ credibility of actors ■ established reputation of actors	■ investment resources ■ civil society commitment (working hours, expertise)	■ political power ■ management power

potential. However, we looked for an approach that allowed for cross-project evaluation and the examination of RwLs as settings (rather than individual experiments). Our approach is intended to complement existing frameworks by assessing the impacts beyond the timeframe of individual projects, and by using broad empirical categories to capture the more intangible, cross-cutting, and long-term effects that may emerge from TDTR. The assessment itself should also be based on an easily accessible tool that allows for a transparent transdisciplinary process; for the RwL approach this is termed as co-evaluation by Wanner et al. (2018).

As a result, we focused on the empirical testing of Giddens' structuration theory (1984) to evaluate TDTR formats with their intended effects on the structures of social systems, as conceptually proposed by Schneidewind et al. (2018). As a starting point for operationalising Giddens' four structuration modalities (i.e., interpretative schemes, norms, allocative resources, and authoritative resources) we adopted the subcategories proposed by Schneidewind et al. (2018) (table 1), with the aim of empirically proving and further developing them into valid indicators for structural change in and through urban RwLs.

Empirically, we draw on a series of six TDTR projects carried out between 2014 and 2021 in the Mirke neighbourhood in the city of Wuppertal, Germany[1] (table 2). The projects focused on different objectives, but they shared the basic aim of creating a positive environment for co-productive city-making (CoCM; i.e., fostering a collaborative style of governance and driving local, bottom-up development). Wanner (2023) highlights a definite increase in the level of activity undertaken by relevant civil society actors, together with local academic institutions engaged in CoCM in Mirke, replacing governmental interventions as the main driver of development in the neighbourhood. What remains unclear is the differentiated analysis of how the TDTR activities, overall, have contributed to producing new structures for CoCM in Mirke.

1 Bernert et al (2024, in this issue) also explores a case study of a long-term RwL in the medium-sized town of Lüneburg, Germany.

TABLE 2: Overview of the six projects analysed in the study. FACE = Faculty of Architecture and Civil Engineering, University of Wuppertal, *F:M* = *Forum:Mirke* (civil-society exchange platform), NE = Neue Effizienz (affiliated institute of the University of Wuppertal for energy efficiency), tz = transzent, WI = Wuppertal Institute, *US* = *Utopiastadt*.

PROJECT NAME	PARTNERS[a]	YEARS	OBJECTIVE[b]	BUDGET[c]
Sustainable business models for Utopiastadt modules°	tz, *US*	2014/15	analysing and designing business models for sustainable activities in *US*	no own project budget, part of a master's programme
WTW – Wellbeing transformation Wuppertal°°	tz, WI, *US*, *F:M*	2015–2018	analysing and fostering activities and structures of co-productive city-making in Mirke	about 1.1 Mio € (no budget for practice partner)
Transformationsstadt – GeoPortal for the good life°°	ts, WI, *US*, NE	2017–2019	designing and programming an open-source digital map for places and actors with a common good interest	about 0.5 Mio € (limited budget for practice partners)
Urban up – upscaling strategies for an urban sharing society°°	tz, *US*, WI	2018–2023	analysing and fostering processes of preserving and developing spaces for sustainable urban development	about 2.2 Mio € (limited budget for practice partners)
SDE – Solar Decathlon Europe 2021/22°°	FACE, *US*, WI	2018–2022	developing and organising an international students' competition on sustainable architecture and housing; on-site event with 16 international teams and their house exhibits; analysis of the effects of the event on neighbourhood development	about 12 Mio € (project partner with own funding for employees and acquisition of land)
NUP – new urban production°	WI, *US*, tz	2020–2022	analysing and fostering practices of sustainable urban production and manufacturing, mostly on the *US* campus	about 0.8 Mio € (project partner with own funding for employees)

[a] Only those partners relevant to the Mirke subproject are listed. | [b] Only the subprojects' objectives. | [c] Overall project budget. | ° Whole project focuses primarily on *US* and/or Mirke. | °° Only a subproject/extensive work package focuses on *US* and/or Mirke.

Hence, we address two research questions:

- ***RQ 1:*** What effects of science-practice co-operation on CoCM in the RwL *Mirke* can be empirically identified by using structuration theory?
- ***RQ 2:*** To what extent do the subcategories proposed by Schneidewind et al. (2018) contribute to a better understanding of the structuration effects of the RwL, and how can they be further developed?

A structuration theory approach

Structuration theory was introduced by Giddens (1984) and has inspired a significant volume of work in the field of transformation research (Geels 2011, Kok 2023). The key notion of the duality of structure informs our understanding that actors are embedded in structural contexts, thus their agency is both constrained and enabled by structures. Yet, simultaneously, structure only exists due to actors producing and reproducing it. Structure-agency dynamics thus offer an analytical lens for studying both stability and transformation. However, there is a long-standing debate in transformation research concerning the empirical applicability of structuration theory and particularly its (in-)ability to track how concrete action relates to large-scale social change (De Roeck and Van Poeck 2023).

We refer to the modalities of structuration as depicted in the original work by Giddens (1984). He theorised that knowledgeable actors draw on rules and resources to exercise transformative capacity. Both terms (i.e., rules and resources) include two further elements. *Rules* can be divided "into modes of signifying or meaning constitution [interpretative schemes] and normative sanctions [norms]" (Giddens 1984, p. 28) that "centre upon relations between the rights and obligations *expected* of" actors (Giddens 1984, p. 30). *Resources* can be divided into allocative and authoritative resources. Giddens defines both forms of resources as being "involved in the generation of power", with allocative resources being "material resources [...], including the natural environment and physical artifacts" and authoritative resources being "non-material resources [...], deriving from the capability of harnessing the activities of human beings [and resulting] from the dominion of some actors over others" (Giddens 1984, p. 374).

Giddens stresses the horizontal interconnectedness of the four modalities, and the importance of the non-material rules alongside the more tangible resources for exercising power. Consequently, we follow Schneidewind (1998, p. 143 f.), who draws on Ortmann (1995), in his interpretation that power is not only established by means of resources but also includes and needs cognitive and normative rules. Consequently, all four modalities should be considered when analysing or initiating transformative action (intentional or unintentional) that changes structural properties. Various differentiations have been proposed to specify and operationalise the modalities (Giddens 1984, p. 258, Ortmann 1995, p. 60). We build our analysis on the ten subcategories proposed by Schneidewind et al. (2018) for the evaluation of RwLs (table 1).

These subcategories have been postulated conceptually based on the RwL project experience in Wuppertal and beyond. Apart from a loose reflection of an RwL project in terms of the four modalities by Gerhard (2020), the subcategories have not yet been empirically tested and refined.

With the aim of empirically observing, refining, or adding to these subcategories, we apply structuration theory by studying how actors in TDTR draw on rules and resources in social interactions situated in the spatial context of an urban neighbourhood, and how this eventually leads to observable changes in the rules and resources shaping its governance mode.

Mirke case study: A series of transdisciplinary and transformative research projects

The neighbourhood of Mirke in Wuppertal, Germany, is home to around 8,600 residents from almost 100 different nations.

Until 2012, Mirke's population was decreasing and the neighbourhood was considered outdated and problematic, despite various redevelopment programmes (Stadt Wuppertal 2014). However, thanks to the community-led conversion of a former railway line into a cycling, walking, and leisure pathway, combined with diverse activities undertaken by the creative cluster, *Utopiastadt,* and other public interest actors, a dynamic network of self-confident and well-organised actors has emerged. Since 2014, the city's scientific actors, especially the Wuppertal Institute and the Center for Transformation Research and Sustainability at the University of Wuppertal (transzent), have also participated in this development. Between 2014 and 2023, six consecutive TDTR projects were carried out, framing *Utopiastadt* and the neighbourhood of Mirke (as the societal context) as an RwL. The projects' objectives and themes differed, but they all aimed to strengthen the structural capacity of CoCM in the neighbourhood (table 2). Following Wanner (2023), CoCM is understood as discursive and/or physical and tangible contributions to a sustainable urban or neighbourhood development made by non-sovereign actors.

Material and processing

The data basis for this article are three co-evaluation workshops that took place in 2021 (online supplement, appendix 1[2]). The participants in the first two workshops were involved in one or more of the six projects, and the evaluation basis evolved from these workshops. The participants were selected to match the project teams which are seen as the actors in the structuration process. The third workshop was intended to reflect and contrast the internal perspective with an external view from local stakeholders from civil society, politics, and local business. The workshops were conducted online, recorded, and transcribed.

The transcripts were analysed applying qualitative content analysis (Mayring and Fenzl 2014, Kuckartz 2018), using the soft-

ware programme *MAXQDA*. Mostly inductive, but also deductive, codes were used and generated (online supplement, appendix 2[2]). The codes were summarised in the form of key sentences.

Results

Regarding RQ1, activities linked to all four modalities were undertaken and developed across the six projects, but with differing prevalence and distribution (figure 1).

We found that the projects improved the capacity for CoCM in all the modalities. Regarding *interpretative schemes,* the coining of new terms and narratives around transformation and experimentation (i. e., key statement A1 = KS A1; table 3, p. 106) and the perception of the Mirke neighbourhood as an independent neighbourhood (KS C1) were mentioned the most. The coining of new terms was contentious. Although this expanded the horizons and helped to further integrate the group of participants, it also had the negative effect of excluding actor groups less familiar with academic language. Undesirable developments were also highlighted (e. g., poverty, lack of education, and the fear of gentrification), illustrating that the project activities at least helped to raise awareness.

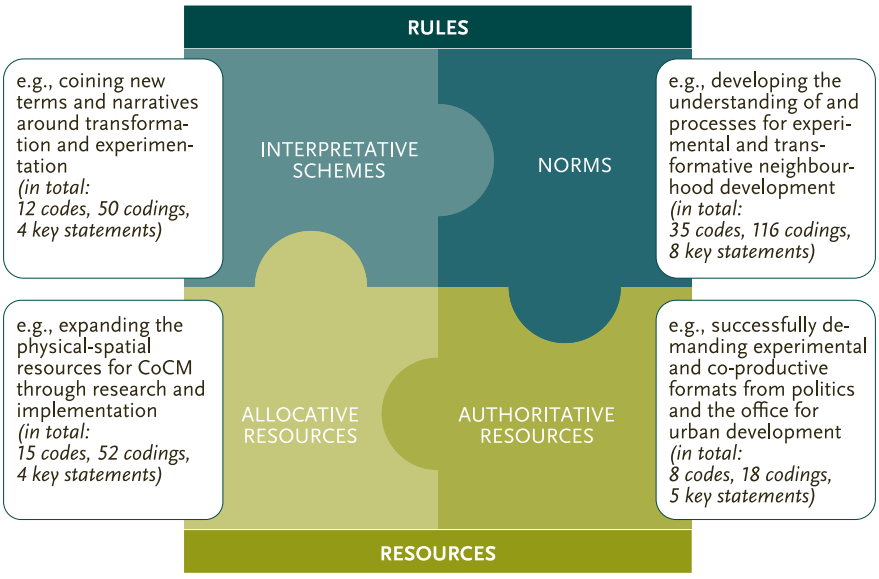

FIGURE 1: Simplified representation of Giddens' concept of rules – divided into the modalities of interpretative schemes and norms – and the concept of resources – divided into allocative and authoritative resources. According to Giddens (1984), the four modalities are fundamental to conceptualising the development and use of power. They influence each other in a reciprocal manner and are, therefore, presented as interlocking jigsaw pieces. In the text boxes, we have included illustrative, empirical examples from the Mirke case for each modality. Each box contains a key sentence about how the respective modality was addressed or influenced, and we list the empirical material that was developed for the present analysis. Codes are labels or tags we developed both inductively and deductively from the concepts, ideas, or themes identified in the workshops. Codings are the specific instances where a code is assigned to the empirical material. We developed key statements as the overall concept for a group of adjacent codes. See table 3 (p. 106) for a list of all the key statements and the online supplement for the list of codes (appendix 2[2]). CoCM = co-productive city-making.

In terms of *norms,* the participants mostly mentioned and discussed the extensive conceptualisation and testing of communication and working practices in TDTR settings (KS H1). Participants stated that stable and constructive communication was both the result of – and the basis for – the series of projects, and it was perceived as being highly valuable for all. The benefit of regular reflection sessions was highlighted. The special format and structure for research exchange, called *Coforschung,* was deemed positive for exchanging ideas and projects beyond day-to-day business (KS E3). However, criticism was voiced regarding the design of the CoCM activities. The events were perceived as often exclusive and too far removed from everyday issues (KS F1). Although the projects claim high levels of participation and inclusion, there were barriers to developing stable norms, and rules for achieving these standards (e. g., limited project resources, time constraints, lack of access to all communities, and the top-down selection of themes).

Regarding *allocative resources,* the comprehensive and stable level of volunteer resources for CoCM (KS J1) was highlighted. This was seen both as a strength of the RwL community, and as a problem due to the unpredictability of these resources and the potential for personal overload. The capacity of the research-practice consortia to access funding for researching and establishing the activities of CoCM (KS I1) was praised. However, there was also disappointment that many activities still rely solely on this temporary funding. It was also mentioned that the stable transdisciplinary co-operation is viewed positively by external actors, making it easier to attract new staff. The expansion of the physical-spatial resources for CoCM (KS L1) was highlighted, especially the successful acquisition of 36,000 square meters of brownfield site by *Utopiastadt* (funded by the project *Solar Decathlon Europe 21/22*).

There were fewer comments concerning *authoritative resources.* An increase in the CoCM actors' confidence was noted, demonstrated by their success in demanding experimental and co-productive formats from local government and the office for urban development (KS M1). Building and strengthening an extensive network and the community of CoCM actors (KS O2), especially through a strong media presence, was viewed as a positive. However, the participants felt that the CoCM activities could and should become more strategic and entrepreneurial. >

2 https://doi.org/10.14512/gaia.33.S1.15.suppl

TABLE 3: Subcategories for evaluating and reflecting on the effects of urban real-world laboratory projects as an operationalisation of the empirical application of Giddens' four modalities. The table is organised by the modalities (shaded quadrants). Each encompasses three or four subcategories on structuration (left-hand columns, numbered A to O). The right-hand columns contain all the empirical key statements found in RQ1. They were used as an empirical test value for the subcategories by Schneidewind et al. (2018). Proposed new subcategories are in bold. CoCM = co-productive city-making, i.e., fostering a collaborative style of governance and driving local, bottom-up development.

	INTERPRETATIVE SCHEME		NORM	
RULES	**SUBCATEGORIES**	**EMPIRICAL EXAMPLES COCM MIRKE**	**SUBCATEGORIES**	**EMPIRICAL EXAMPLES COCM MIRKE**
	A) shared notions/ terms	A1) coining new terms and narratives around transformation and experimentation	E) rules of legitimised interventions	E1) developing the understanding of and processes for experimental and transformative neighbourhood development
	B) shared narratives	B1) promoting the perception of the Mirke neighbourhood as a positive example of CoCM		E2) beginning to think about rule-based containment of undesirable developments, such as the gentrification or the commercial exploitation of the spaces created for and by the common good
	C) local identity	C1) promoting the perception of Mirke as an independent neighbourhood		E3) creating rules and offering structures for research exchange through *Coforschung* and thus generating a platform for exchange beyond day-to-day business
	D) shared problem understanding	D1) visible communicative thematisation and discussion of undesirable neighbourhood developments	F) credibility of actors	F1) designing CoCM activities as events with certain access barriers and a perceived exclusivity and distance from everyday issues and problems
			G) established reputation of actors	G1) increasing the relevance, visibility and legitimacy of CoCM activities through the integration of research
			H) rules for co-operation in teams	H1) extensive conceptualisation and testing of communication and working practices in transdisciplinary research and application settings, including learning from previous projects
				H2) increasing the self-evidence and regularity of reflexive thinking through the participation of research
				H3) gathering experience on and developing concepts for involving volunteer resources for CoCM
	ALLOCATIVE RESOURCES		AUTHORITATIVE RESOURCES	
RESOURCES	**SUBCATEGORIES**	**EMPIRICAL EXAMPLES COCM MIRKE**	**SUBCATEGORIES**	**EMPIRICAL EXAMPLES COCM MIRKE**
	I) investment resources	I1) acquiring and maintaining the capacity of research-practice consortia to use funding backdrops for researching and establishing the activities of CoCM	M) political power	M1) successfully demanding experimental and co-productive formats from local government and the office for urban development
	J) civil society commitment (working hours, expertise)	J1) continually and successfully involving the necessary volunteer resources for CoCM activities		M2) beginning to influence the higher level of funding allocation and funding policy
			N) management power	N1) *Utopiastadt* developing administrative skills as project manager
	K) knowledge (explicit, tacit, implicit, local, etc.)	K1) generating knowledge resources (project products, publications, theses and articles in the *Coforschung*, etc.)	**O) convening power**	O1) acquiring and maintaining the ability to communicate with the public and activate people
				O2) building and strengthening an extensive network and community of CoCM actors
	L) spatial resources	L1) expanding the physical-spatial resources for CoCM through research and implementation projects (e.g., access to land, in-between use of buildings)		

Putting the subcategories to the test

For RQ2, we were able to assign at least one empirical example to every subcategory proposed by Schneidewind et al. (2018) (table 3). Additionally, we found eight key statements not covered by these subcategories. We therefore propose five new subcategories.

Discussion

Application of structuration theory to the case of co-productive city-making in Mirke

Our results provide evidence about how the lens of structuration theory can help to disentangle the production of new structural properties for CoCM according to the four modalities. The results indicate that resorting to the modalities of interpretative schemes and norms is equally as important for building power, as resorting to the classical instruments of power (i. e., resources). The modalities only form a complete picture in combination with each other (figure 1). This picture then shows not only how the capacities of CoCM benefit from the TDTR projects, but also where and how current power dynamics limit CoCM.

The participants noted the continued dependence of CoCM on active individuals and the instability of research funding. This makes it questionable whether CoCM has yet reached the level of structure with "absence of the subject" (Giddens 1984, p. 25). Literature on co-production also states that bottom-up activities are dependent on "[...] effective administrative structures, processes and coordination" (Sorrentino et al. 2018, p. 286). The limited governmental coordination is felt in Mirke. Overall, the structuration perspective shows that there is still room for improvement in the structural power of CoCM. This aspect could be linked to the general idea of RwLs as permanent research infrastructures (with the relevant permanent resources) instead of temporary formats. This insight supports the need to develop social entrepreneurial action in support of CoCM, and a further strategic close alliance between civil society actors, local government, and research institutions. Although we have already reviewed around eight years of development in this article, the long-term effects on the structure of CoCM are still unclear and should be examined by future research.

Reflecting on the general use of structuration theory and the subcategories

Using structuration theory for evaluating TDTR projects has demonstrated its applicability for the following reasons. First, it is well-suited for TDTR evaluation settings due to its open, transparent, but well-guided format[3]. Secondly, the practical and societal benefits are clearly in the foreground of the analysis. Furthermore, the scheme of the four modalities is, as our participants reported, easy to understand and more likely to motivate participation than overwhelming technical questionnaires. The four modalities provide a comprehensive framework covering the central explanations of how to influence social transformation processes at a higher level of abstraction, while also identifying gaps and weaknesses in the projects' ambitions.

The theory also contains further potential. For example, it can be useful to analyse spatial transformation processes, as Werlen (2012) highlights. The understanding of structure as referring "to the structuring properties allowing the *binding* of time-space in social systems" (Giddens 1984, p. 17) may prove helpful for analyses of transformations in social science. Structuration theory thinking is also already used for unravelling power dynamics and strategic action (Fligstein and McAdam 2011). This was demonstrated in Mirke in the analysis of the power play for interpretative authority and the development of a large brownfield site, the *Utopiastadt* Campus (Wanner et al. 2021).

Consideration should also be given to certain limiting factors to the theory. Using structuration theory to analyse a case is an interpretative and discursive process. The evaluation and theory-driven description of the dynamics between agency and structure needs explicit system boundaries (e. g., time, space, evaluation focus, societal system) and a clear explanation of the context.

Resorting to the modalities of interpretative schemes and norms is equally as important for building power, as resorting to the classical instruments of power (i. e., resources).

The approach does not deliver a final assessment of whether a particular project was successful or not; instead, it has explanatory power regarding processes, resources used, and the interrelationships between material and non-material resource deployment. The theory does not build on a serial understanding of input-process-output-outcome; instead, it promotes the idea of recursive dynamics of agency and structure and, therefore, does not elucidate serial impact chains.

In terms of the subcategories drafted by Schneidewind et al. (2018), we can confirm ex-post that our case covers all these subcategories. This indicates that they are applicable to the evaluation of urban RwLs, can be roughly demarcated from each other, and cover a broad range of effects linked to the modalities. However, some key statements could not be assigned to any of the existing subcategories. We therefore propose five new subcategories to match our empirical material. These are: 1. shared problem understanding, 2. rules for co-operation in teams, 3. knowledge (explicit, tacit, implicit, local, etc.), 4. spatial resources, and >

3 We considered it important to have both a scientific and a practical approach to the material. Consequently, a copywriter and a designer developed a four-page "newspaper" with their interpretation and illustration of the workshops: *https://quartier-mirke.de/flughoehe-stadtmachen-zwischen-wissenschaft-und-praxis*.

5. convening power. The first three reflect qualities of good transdisciplinary research and have been frequently mentioned in relevant TDTR literature (e. g., Lang et al. 2012, Pohl et al. 2017). The access to spatial resources reflects the ambition of RwLs as infrastructures for the provision of appropriate spaces for experiments and transformation (Bergmann et al. 2021). Convening power is required in transfer and participation-oriented research processes, and is mentioned in TDTR formats and in transition management (Stirling 2014).

A potential criticism of the subcategories is that they are often too simplistic and ambiguous. For example, the distinction between shared narratives and local identity is blurred. Likewise, civic engagement is not clearly defined. From an economic point of view is it an opportunity cost, or does the term intend to emphasise a special motivation and voluntary willingness to work? The new subcategory of knowledge is also broad and unclear in terms of novelty or the recombination of knowledge and is difficult to ground in Giddens' theory (1984). For Giddens (1984), knowledge is a resource that hovers above the modalities and is at least questionable for inclusion in his more material notion of allocative resources. Moreover, some subcategories, such as shared problem understanding and rules for co-operation, relate also to the processes involved, not only the effects.

Therefore, we consider the subcategories more as individual results than as an already empirically saturated list of criteria. In summary, while they may be theoretically ambiguous to an extent, the subcategories are, in our view, thought-provoking and represent a step forward in constructing a manageable evaluation tool for TDTR projects. They can now be considered as an empirically supported proposal for the operationalisation of Giddens' modalities (1984), which until now have been available only as a general theoretical framework for open reflection. We argue for their general applicability in urban RwL settings and look forward to their further examination.

Conclusion

There is an ongoing debate about how to evaluate, track, and explain the societal impacts of TDTR formats such as RwL settings. Building on Giddens (1984) and Schneidewind et al. (2018), we present an evaluation approach rooted in structuration theory. We applied the theory, with its four modalities (interpretation schemes, norms, allocative resources, and authoritative resources), to the case of the Mirke neighbourhood in Wuppertal, Germany, where six consecutive TDTR projects promoted the capacity of CoCM. A joint process of co-evaluating the structuration effects of the projects on CoCM led to 21 key statements within the four modalities. These interrelated statements reveal and explain the dynamics of how and with what means the actors in the science-practice co-operation tried to foster CoCM and aimed for structural change in terms of making new rules and gaining access to resources to support their activities. The process also identifies the risks and weaknesses of these strategies.

Previously proposed subcategories were explored as an empirical operationalisation of the modalities. All ten subcategories were confirmed as being applicable, and five new ones were generated. We encourage the further development and grounding of the subcategories, both theoretically and empirically. Apart from its ability to generate empirical findings, our approach proved to be practical in a transdisciplinary setting, was focused on real-world effects and was helpful in inducing knowledge integration and reflection at the science-society interface.

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