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Transdisciplinary Research along the *Logic of Empowerment*: Perspectives from Four Urban and Regional Transformation Projects

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Abstract: Transformative research requires transdisciplinary collaboration, forcing researchers out of their disciplinary comfort zones. In transdisciplinary research projects, the role of (social) scientists changes, and non-scientific actors become part of research projects. Transdisciplinary research is particularly suited to not only generate scientific knowledge, but also invent real-world solutions and to innovative. This, however, does not come without challenges. Implementing a transdisciplinary project is time-consuming and requires the alignment of both the research and impact ambitions of all project partners. In this paper we build upon experiences gained in four transdisciplinary research projects and ask: (1) What is the transdisciplinary approach followed by the project? (2) Which opportunities and challenges can be identified for successful transdisciplinary collaborations? (3) What is the rationale for engaging in transdisciplinary research from the perspective of social scientists? Building upon the logics of interdisciplinary, a fourth logic, called the *logic of empowerment*, is identified as a driver for transdisciplinary research. Transdisciplinary collaboration empowers researchers to not only 'discover' innovations, i.e., to invent, but also to implement, i.e., to innovate.

Keywords: transdisciplinary; transformation; empowerment; living labs; knowledge production; climate change adaptation; resilience

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1. Introduction

One of the basic premises of transdisciplinary research is that it generates 'real-world' innovations that directly benefit society [1–3]. Although disciplinary science keeps its value in generating (basic) scientific knowledge, inter- and transdisciplinary approaches are considered exceptionally suited to 'invent' practicable solutions, i.e., to lead to innovations [4–6]. Although 15 years ago, Pohl et al. [7] (p. 420) found that "conventional research funding sources [are] reluctant to support transdisciplinary integrated research" they also noted that funding bodies were giving more priority to transdisciplinary research. Funding increasingly aims at inter- and transdisciplinary teams [8] that not only receive the assignment to generate scientific knowledge, but also innovations that lead to direct practical solutions. This redirection of budget is possibly made the most explicit in European funding schemes such as Horizon2020, which make an explicit distinction between research and innovation actions, and urge scientists to descend from their ivory tower and connect to the 'real world'.

The emergence of Science Mode-2 [6,9], the Triple Helix [10,11], and the Entrepreneurial University [12,13] recognizes from each respective angle the need for science to be socially distributed and economically embedded, and calls for innovation development to be a transdisciplinary effort. This emergence calls for the integration of science in society. At

the same time, a trend towards living labs as locations for co-production of knowledge in participatory transdisciplinary settings to deal with pressing real-world problems such as climate change adaptation or social inclusion and empowerment can be observed in the literature (e.g., [14–16]). Although not strictly necessary, such living labs are often initiated and managed by actors from universities. The aim of living labs is usually to develop real-world innovations or interventions. This pushes the role of social scientists away from that of an 'external' observer analysing societal developments, and instead pulls researchers into transdisciplinary modes of knowledge and innovation production. The role of (social) scientists changes, and non-scientific actors are becoming part of research projects [17]. This, however, does not come without challenges.

Implementing a participatory transdisciplinary project in which scientific and non-scientific actors collaborate on equal terms, requires the alignment of both research and impact ambitions, of all project partners. Publications by, or on, trans- or interdisciplinary research projects tend to majorly address the outcomes of co-production processes or present ideal typical descriptions or success factors of transdisciplinarity (e.g., [15,17–20]). In contrast, this paper aims to address a research gap by uncovering the dynamics and challenges of transdisciplinary research *from within*. It builds upon Barry et al.'s *Logics of Interdisciplinarity* [4], but recognizes that the logics of *ontology, accountability*, and *innovation* do not suffice to explain fully why researchers engage in time-consuming transdisciplinary projects. A fourth logic, that of *empowerment*, is therefore, identified as a key driver for social scientists to engage in transdisciplinary projects.

This paper analyses findings of four transdisciplinary research projects. The authors were all involved in one or more of these projects, and therefore, reflect upon their own experiences, gathered in various reflection workshops carried out in the team. This paper distils lessons learned and draws conclusions by analysing the individual projects along the following questions: (1) What is the transdisciplinary approach followed by the project? (2) Which opportunities can be identified and challenges for successful transdisciplinary collaborations? (3) What is the rationale for engaging in transdisciplinary research from the perspective of social scientists?

Literature Review: Transdisciplinarity as (New) Mode of Knowledge Production

The assumption that transdisciplinary collaboration will result in project outcomes with bigger potential for applicable knowledge and innovation is the basis of the four projects this analysis is based on. In earlier research, as well as practice on public engagement, the dominant idea was that in order to maximize the chances of acceptance and mainstreaming of (sustainable) alternatives, the involvement of a variety of stakeholders was inevitable (e.g., [21–23]). Widening the group of participants also widens the scope of the research project, and therewith also introduces the researchers to novel ideas that respond more directly to societal needs. Early efforts to engage non-scientific stakeholders in science remained rather superficial, and tended to focus more on science communication than on real co-creation, thus resembling consulting transdisciplinarity rather than actual participatory transdisciplinarity [24]. Instead, "lay and non-expert accounts (. . .) should not be understood merely as perceptions, but recognized as expressions of a kind of scientific citizenship" [4] (p. 37), which are to be incorporated within the research process at equal terms rather than only be consulted. Given the complexity of challenges related to urban transformations, transformative sustainability research requires transdisciplinarity [25,26].

The concept of transdisciplinarity can be traced back to the 1970s [27,28] and has been applied variously by different authors. Lawrence et al. [17] (p. 47) reviewed the literature on transdisciplinarity and distilled the following seven key characteristics: "(1) A focus on theoretical unity of knowledge, in an effort to transcend disciplinary boundaries; (2) the inclusion of multidisciplinary and interdisciplinary academic research; (3) the involvement of (non-academic) societal actors as process participants; (4) a focus on specific, complex, societally relevant, real-world situations or problems; (5) working in a transformative manner, i.e., going beyond the focus on real-world problems to proactively support action

or intervention; (6) an orientation toward the common good (including the betterment of society and a humanistic reverence for life and human dignity); (7) reflexivity, i.e., consciously contemplating the broader context and ensuring the compatibility of the project's components and tasks throughout the course of the project". These seven characteristics are also featured in the projects analysed in this paper in which the definition of transdisciplinarity by Jahn et al. was followed as "a critical and self-reflexive research approach that relates societal with scientific problems; it produces new knowledge by integrating different scientific and extra-scientific insights; its aim is to contribute to both societal and scientific progress; integration is the cognitive operation of establishing a novel hitherto non-existent connection between the distinct epistemic, social–organizational, and communicative entities that make up the given problem context" [29] (pp. 8–9).

Before addressing co-production, transdisciplinary knowledge production, or constellations of stakeholders in innovation processes, it is necessary to take a step back and consider the purpose of the generation of knowledge. What does it mean when we speak of applicable knowledge and innovation—as opposed to scientific or basic knowledge?

In their 1994 book "The New Production of Knowledge", Gibbons et al. [9] coined the term Mode-2, recognizing the emerging trend that the generation of knowledge, especially of practical knowledge, was increasingly achieved in inter- or transdisciplinary settings. Rather than in a purely scientific setting, knowledge was being co-produced in the 'context of application' [9] (p. 3). New actors from outside academia entered the scientific arena. An important driver was the need for knowledge in industry. In the words of Gibbons et al. [9] (p. 13): "the core of our thesis is that the parallel expansion in the number of potential knowledge producers on the supply side and the expansion of the requirement of specialist knowledge on the demand side are creating the conditions for the emergence of a new mode of knowledge production". Mode-2, therefore, has a strong economic, market-based, rationale at its core. This economics approach is even more pronounced in the Triple Helix model, which was first defined in 1995 [11], as it explicitly aimed at the knowledge-based economy. Within the Triple Helix model, "the relationship among university, industry and government as well as within each of these spheres [is transformed]. As institutions increasingly 'take the role of the other', the traditional match of institution to function is superseded" [10] (p. 295). Universities, industry and government are considered the institutional carriers of the innovation system, within which one of the key functions is "wealth generation in the economy" [30] (p. 43).

These, by now 'traditional,' theories of the changing roles of universities and their relationship with society, thus tend to be in line with a market-based economic logic. Universities (researchers) have to engage in (transdisciplinary) collaboration to increase the accountability of their work, as well as to contribute to innovations needed within the rationales of a knowledge economy (cf. [4]). These envisioned innovations are primarily technological innovations that have the potential of being commercialized. This market-based approach to innovation is still dominant (cf. [31]) and can be witnessed in concepts such as the entrepreneurial university [12,13]. As summarized by Audretsch, "the role of the entrepreneurial university is to create new businesses, ventures and commercialization where it previously did not exist, or at least to increase the amount of technology transfer from the university to private and not-profit firms and organizations" [32] (p. 319). Nevertheless, there is increasing awareness that innovations need not be commercial and innovations need not be primarily technological (e.g., [33,34]).

Although the role of consumers (mainly in their role as users) has also been increasing in reference to the development of technological innovations [35–37], civil society takes an even more central position in non-technological innovations. Civil society as a source of knowledge has entered the idea of the Triple Helix as a fourth helix into the quadruple helix [38]. Besides universities, industry, and government, civil society is added as a fourth helix, interacting with the institutional carriers of the innovation system as an additional source of knowledge (Carayannis and Campbell have also described this as a Mode-3 of knowledge production [38]). Expanding upon Mode-2 and the Triple Helix model,

transdisciplinary research projects—especially those aiming not only at the development of technological/commercial innovations—therefore, (ideally) engage representatives of all four helices.

Transdisciplinary collaboration does not come without its challenges though; "one virtue you need when working in transdisciplinary research: patience. You must be very patient indeed" [5]. So, what motivates researchers to engage in transdisciplinary collaboration—if the goal is not commercial/entrepreneurial? As discussed by Barry et al. [4] (p. 31), one logic of interdisciplinarity is increased accountability, "breaking down the barriers between science and society". Although this may be present at a larger strategic level, thinking along the lines of the position of the university within society—the social contract—this seems less relevant for the individual researcher. The logic of innovation and an ontological logic, on the other hand, do drive transdisciplinary research. There are limitations to the applicability of scientific expertise, especially when addressing complex challenges with very local impacts and solutions such as climate change adaptation. Developing workable solutions, therefore, not only requires collaboration across scientific disciplines, but also with other local stakeholders, including public administration, (local) companies, and citizens.

Although Barry et al. [4] follow a rather liberal interpretation of the concepts of interdisciplinarity and transdisciplinarity, including also non-academic collaborations under the header of interdisciplinarity, it is worth distinguishing between them. When speaking of transdisciplinarity, we refer to collaborations beyond academic partnerships, with non-academic partners [39] as 'non-certified experts' [40,41].

Whereas transdisciplinary collaboration is oftentimes put forward as necessary for success, the collaborative process itself may involve contestation and struggles [18]. Transitions towards sustainable solutions aim at collective benefits, but may bear individual costs. A windmill, for instance, benefits all through reduced emissions, but may negatively influence the quality of life of those living in its direct vicinity. Addressing sustainability or climate change challenges almost always involves competing interests. Balancing these interests is a delicate task and it is bound to backfire if not all interests are properly represented early on in the process. Whereas early attempts at introducing public participation for sustainability majorly invited the public to comment on already defined plans, the focus has shifted to engagement in earlier stages of the process, aiming at co-producing solutions. Transdisciplinary research follows this line of reasoning and aims at integrating a multitude of actors to co-produce applicable knowledge. This, however, creates challenges. As put by Caniglia et al., the intentional design of transdisciplinary projects aiming at generating action-oriented knowledge "is embedded in social processes of confrontation, negotiation and deliberation" [3].

Addressing real-world problems in research projects implies several tensions [18]. Collaboration requires a certain openness from all actors involved. Participants need to be open to different perspectives and have to be willing to learn from other stakeholder groups. As these different perspectives cannot all be taken into consideration in the proposal stage, transdisciplinary research projects require a flexible design. "Real experiments are open-ended. This openness to the process means that a greater degree of flexibility and effort is required than is the case in other research projects; there is only limited predictability. This is exacerbated by the fact that a real experiment takes place in a real-world environment that cannot be controlled. External political changes, new local conditions, but also internal group processes make them sensitive and highly dynamic undertakings" [42] (p. 235, own translation). Open-endedness brings uncertainty and therewith risks. It may lead to conflicts if the project does not develop in the intended or expected direction, or if not all interests of all participants can be met.

The next sections introduce the four transdisciplinary research projects that lay at the heart of this paper's analysis. Section 4 presents the results from the qualitative assessment of these projects, addressing the opportunities and challenges. Section 5 concludes by high-

lighting the logic of empowerment as a driver for scientists to engage in time-consuming and challenging transdisciplinary research projects.

2. Materials and Methods

This section introduces the four projects on which the analysis is based. Within the project description, the transdisciplinary approaches are introduced and analysed. At the time of the first conceptualization of this paper, all co-authors worked as social scientists at the TU Dortmund University, Social Research Center (TUDo/sfs). As mentioned explicitly in the definition of Jahn et al. [29] (p. 8) of transdisciplinarity (cited above), transdisciplinarity is a "critical and self-reflexive research approach". This reflection took place within the projects (see below), but also on a cross-project level. The project processes were discussed and analysed regularly at internal team meetings. Within these meetings, success factors, as well as challenges and barriers to transdisciplinary collaboration and project management were analysed. The rationale to engage in transdisciplinary research from the perspective of the researchers also featured in these discussions as the leading questions in these reflexive meetings where, on the one hand, 'what lessons can be drawn from the transdisciplinary processes within the respective projects?', and on the other hand, 'what do we, as social scientists, gain from engaging in these time-consuming processes?'

The selection of these specific projects was a pragmatic one, as the authors had insights from within the ongoing or recently finished transdisciplinary projects.

The first project, KoSI-Lab ("Municipal Laboratories for Social Innovation") (Project description based on [43]. The project was funded under the research and innovation programme "Innovative Municipalities" by the German Federal Ministry of Education and Research from 2016 until 2019 (Grant agreement number: 033L174A-E), was initiated and coordinated by (some of) the authors. The aim of KoSI-Lab was to develop two labs for social innovation (SI labs) in the cities of Dortmund and Wuppertal. A real-world lab approach was used as a research design to investigate how municipal SI labs contribute to setting up a new collaboration model and supportive infrastructure between the public sector and civil society. The project was framed by a wider discourse on social innovation [44–46], as well as public sector innovation and collaborative governance [47–50]. KoSI-Lab was managed by researchers from TUDo/sfs. Further scientific partners were the Wuppertal Institute for Climate, Environment, Energy and the ILS Institute for State and Urban Development Research, Dortmund. Practice partners in Wuppertal were, on the one hand, the public participation and civic engagement unit of the city of Wuppertal and the non-profit association "Centre for good deeds" (Zentrum für gute Taten e.V.). In Dortmund, the municipal economic development agency was a practice partner. In accordance with the transdisciplinary approach, the work packages in the project were developed and implemented along the dimensions of problem constitution, participation of social actors, knowledge integration, and transferability of results [26,39,51].

A collaborative network was built with the support of the scientific actors of the Wuppertal SI-Lab to implement a system of reusable coffee cups, which involved actors from civil society, a bakery chain, and the public administration. In Dortmund, the collaboration between researchers and the municipal economic development agency resulted in the establishment of a social innovation centre.

In order to establish the real-world laboratory contexts, the (research) questions were reformulated together with all partners at the beginning of the project. The tasks and responsibilities of the work process were determined, and the expectations, possibilities, and limits of the project context were discussed. The scientific partners of the project developed preliminary studies in the form of project reports on relevant topics. In consultation with the practice partners, the scientific partners created a mapping of already existing socially innovative initiatives for both cities. The findings from the preliminary study reports and the mapping then flowed into the preparation of city dialogues, as well as the concept development for both labs [52]. In the course of developing the concept, the real experiments for single-innovation processes within the labs were planned. It must be

considered that the concept development with the practitioners can also be understood as a real experiment. Various methods were used to reflect on the real-world experiments in the project [42]. Among other things, there was an annual supervision provided by researchers from the ILS, who conducted focus group discussions with the project participants. Focus group discussions took place with the project groups within each city, as well as with the whole project consortium.

The second project, iResilience (Social Innovations and Smart Urban Infrastructures for the Resilient City of the Future) (Project description based on [53,54]; see also [55]. iResilience was funded by the German Federal Ministry of Education and Research from 2018 until 2022 (Grant agreement number 01LR1701B1), was initiated and coordinated by TUDo/sfs. The aim of iResilience was to design and test new social practices and technologies in transdisciplinary living labs to continuously improve urban resilience to climate change. iResilience broadened the scope of solutions on urban climate resilience by working out the potentials of social innovation and digital innovation in collaborative living labs. The concept of social innovation aims at an intentional targeted change of practices [33] and introduces social considerations in the resilience discussion, which is often dominated by technical measures. Social innovation opens up opportunities for different social practices in dealing with the impact of a more climate-resilient city, such as choosing shaded walkways on heat days, different mobility patterns, or working together for green areas in neighbourhoods. As such, social innovation goes beyond the inclusion of a higher degree of participation in planning processes.

iResilience was set up as a transdisciplinary project. It was coordinated by the social scientists of TUDo/sfs and it included engineering science competences and urban planning expertise. The German Institute for Urban Affairs (Difu) was also involved as a project partner. Within iResilience, Difu participated as a social science partner, but due to its role as a consultant for German municipalities, it also performed a transfer role between science and municipal practice. Next to these scientific partners, the private company Dr. Pecher AG brought in hydrological expertise. Finally, the cities of Dortmund and Cologne were project partners involved in the research project. The city of Cologne was represented by the city's Department for the Environment and Consumer Protection, as well as the municipal drainage company.

The project sought to work with citizens and local government actors to design processes and measures that contribute to urban climate resilience. The project was coordinated by academics, but the local administration of the city partners comprised active members of the project consortium, jointly steering the research. The cities were not only the subject of a research project aiming at introducing a new mode of transdisciplinary governance, but they were actively involved in shaping the process and experimenting with, and alternating, their approaches to citizen engagement and knowledge co-creation for climate change adaptation. The aim of the project was threefold: (1) Bridging the gap between policy-making, public administration, citizens, and other local stakeholders, by collaborating in various governance formats, opening new venues of city–citizen interaction; (2) promoting knowledge co-creation and harnessing citizens' knowledge as neighbourhood experts; and (3) collaboratively creating and implementing resilience measures and strategies.

Climate change adaptation and urban resilience were topics of the co-creation process, but even though the project aimed at creating concrete measures, these played a secondary role. The primary aim was to experiment with, develop, and report on innovative, future-oriented ways of transdisciplinary city–citizen collaboration and knowledge co-creation (see [55]). New forms of deep collaboration were considered necessary to trigger transformative changes. However, the project put the process, rather than the outcome, centre stage. There is no single best pathway for transformative change [56], instead the process involved multiple actors in negotiating alternative paths.

The living lab approach framed the transdisciplinary collaborations [57]. The transdisciplinary governance character became clear in that all actors were on an equal level [58]. Actors from different helices of the quadruple helix (university, industry, government,

and civil society) worked together in various settings in so-called 'local action groups' to, for instance, collaboratively install rainwater retention tanks (a collaboration between researchers, local inhabitants, civil society organisations and public administration), or for the development of a street that was vulnerable to flooding due to heavy rain (designed in a collaboration between the municipal drainage company, public administration, researchers from different disciplines, a private company, and local inhabitants). The collaborations allowed generating new knowledge in a mutual learning process by means of bringing together different sets of knowledge and experience of representatives of the different quadruple helices. Practically, this meant that the project aimed to activate citizens and other stakeholders to collaboratively kick-start urban transformations.

The third project, ProPolis (Project description based on [59,60]. ProPolis was part of the research funding measure Urban Climate Under Change $[UC]^2$, funded by the German Federal Ministry of Education and Research from 2019 until 2023 (Grant agreement number 01LP1913E).) (Basics for the Operationalization of PALM-4U—Practicability and Continuation Strategy) was the follow-up project of KliMoPrax (see [61]) within which the practicability of a new urban climate model (PALM-4U) was to be tested and ensured through engagement with the user community of municipal civil servants. Both in KliMoPrax and in ProPolis, TUDO/sfs was on board as social science experts within an interdisciplinary team. Within ProPolis, the project design did not really allow for the co-production of knowledge, but should be seen as knowledge exchange [60], and could, therefore, be rather considered as 'consulting transdisciplinarity' (after [24]). TUDo/sfs organized these knowledge exchange platforms between the research consortium and mainly municipal practice partners, in collaboration with the German Institute for Urban Affairs.

Urban areas and their citizens are highly affected by climate change. Decision-making processes need to incorporate the climate impacts of urban planning [62]. A suitable tool in such processes is urban climate models, which can judge the effects of green, blue or grey infrastructures. ProPolis was funded as one of three modules in the funding measure Urban Climate Under Change $[UC]^2$ (see Figure 1), which aimed at the (further) development of the new urban climate model PALM-4U as a tool for science, but also as a practicable tool for decision-making processes in municipalities. Module A was responsible for the technical development of PALM-4U [63]. The primary task of Module B was the evaluation and validation of the model based on real-world observations and measurements [64]. Module C (ProPolis) studied and aimed to enable the practical applicability of PALM-4U [59]. ProPolis bridged science and practice and enabled transdisciplinary collaboration in the development and implementation of PALM-4U, even if the ideal typical participatory transdisciplinarity could not be reached.

A central task of ProPolis was the development of a continuation strategy, including a transdisciplinary community of practice (CoP). This was linked to the evaluation of the practicability of PALM-4U from a user perceptive and the capacity building of PALM-4U users through trainings, as well as service and support offers. The central method was the implementation of 'Experiment Rooms' (ExLabs) as (largely online, due to COVID-19) meetings that served as a space for exchange of experience and discussion between science and practice. ProPolis built the cross-disciplinary cross-fertilization between the forefront of scientific modelling and the everyday practice of those working in German municipalities.

The fourth, and last, project to be introduced is called Evolving Regions (Evolving Regions is funded by the EU environment programme LIFE and co-financed by the Environment ministry of North Rhine-Westphalia (NRW) from 2018 until 2023 (Grant agreement number: LIFE18-CCA/DE/001105). The aim of the project was to increase resilience against the consequences of climate change at the regional level, focusing in particular on rural regions. The impacts of climate change are oftentimes discussed in relation to cities and urban areas, for instance, related to urban heat island effects or risks of flooding in densely populated areas (e.g., [65,66]). The effects of climate change also impact rural areas though, for instance through droughts [67]. In order to cope with the challenges resulting from

climate change, actors outside the urban centres must also be sensitised to the issue and must be empowered to act in accordance with these challenges.

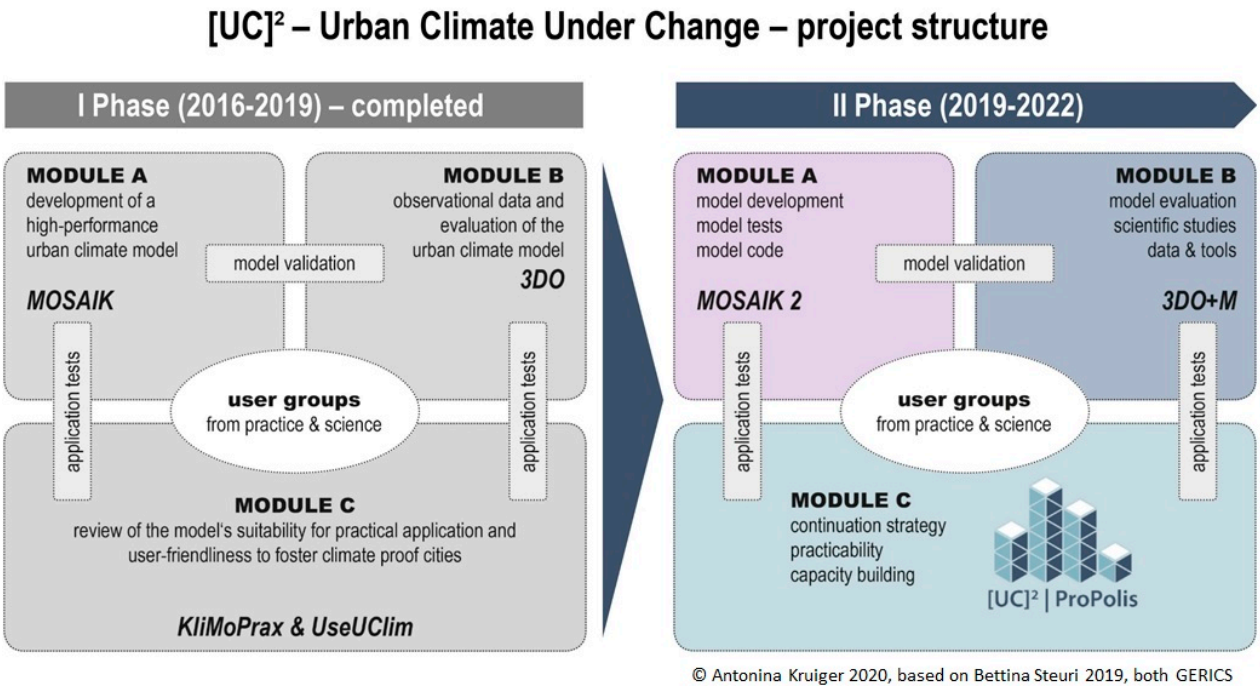

Figure 1. [UC]^2 project structure.

The objectives of the project were to:

- Improve the resilience of the participating regions towards the impacts of climate change;
- Integrate climate change adaptation into municipal and regional planning processes;
- Support regional actors in acquiring competences; and
- Develop a market of climate change adaptation consultants.

The project consortium comprised a variety of partners. TUDo/sfs coordinated the project. TU Dortmund University's Department of Spatial Planning (IRPUD) and the University of Twente were involved as scientific partners. Other partners in the consortium were the Difu, the Prognos AG, the Bildungszentrum für die Ver- und Entsorgungswirtschaft gGmbH (BEW) and ZDF Digital. In addition, seven districts in Germany were involved. The districts were represented by different units in the respective administrations.

Evolving Regions aimed to increase resilience and adaptation to climate change in the participating regions. For this purpose, the regions went through a 19-month process in which regional actors from different thematic fields and sectors worked on a strategy to foster climate adaptation in their region. Through a wide range of support services, the regions were put in a position to actively start climate adaptation and to independently advance it in the future. Based on a detailed climate impact analysis, which was provided to the districts by IRPUD, regional actors from different thematic fields and sectors jointly developed goals, strategies, and measures for climate adaptation in workshops carried out by TUDo/sfs and Difu. Conducted in different cross-sectoral topics, these workshops were designed to promote transdisciplinary collaboration and an integrated approach to climate adaptation, following the method of integrated roadmapping [68]. The regional actors were also provided with knowledge on low-threshold monitoring possibilities and on the use of digital formats and information dissemination via social media. The moderation of the regional processes was partly carried out by consultants who had previously been trained in the process method by TUDo/sfs at the BEW.

Various stakeholders from different areas were integrated in the regional processes. It had been foreseen that all stakeholders that could be relevant for the cross-sectoral

adaptation process would be integrated, these included, e.g., relevant departments in local and district administrations, public utilities and other institutions, local businesses, industry and other commercial organisations, and local politics and parties. Special attention was given when selecting the participants in order to integrate actors with planning, decision-making and implementation tasks and mainstream climate adaptation in each of these levels or tasks.

In the regional dialogues, the knowledge and experiences of the participating stakeholders were used for the improvement of the provided support services (e.g., local knowledge regarding the actual consequences of heavy rainfall events supplemented the results of the climate impact analysis) and at the same time served the continuous development of local measures. Following Schneider and Buser [69] (p. 140), a high intensity of stakeholder integration was needed on the one hand to ensure the awareness raising "about possible future risks that stakeholders had not previously been aware of," in the rather rural regions participating in the project. On the other hand, the project aimed at generating knowledge for sustainable change in the governance and planning structures of the participating regions. To foster the high degree of stakeholder integration, transdisciplinary discussions, workshops and other innovative formats, focused on cross-sectoral dialogue between regional actors on various fields of action in climate change adaptation. Examples of this are cross-sectoral thematic fields that were developed in the regions together with the regional actors in order to structure the process (e.g., the thematic field of 'landscape in climate change', which combined topics such as agriculture, nature conservation or recreation). In addition to the concrete development of climate adaptation measures, this dialogue led to mutual learning processes among the stakeholders involved and, in the best case, to a network of regional climate adaptation in the participating regions, which will continue to exist beyond the project duration.

In order to be able to offer the participating regions the complete climate adaptation cycle, questions, competences, and services were jointly discussed and brought together in advance by the project partners. In addition, the tasks and responsibilities in the work process were determined, and the expectations, possibilities and limits of the project context were discussed. Together with the practice partners, target agreements and focal points were discussed and defined in advance.

3. Research Context

The description in Section 3 introduced the projects and their transdisciplinary framing. The first question introduced above "What is the transdisciplinary approach followed by the project?" has been answered. Let us now turn to the second question and to the core of our analysis. In this section, the results of the analysis regarding opportunities and barriers as witnessed from within the projects is presented.

3.1. KoSI-Lab

Reflecting on the real-world experiments in Wuppertal, it can be stated that the collaboration of all those involved in the KoSI-Lab project team has been a central factor for the project success. This also applies to the cooperation with the entire project network (practice partners Wuppertal and Dortmund and scientific partners), as well as the representatives of civil society actors on site. Collaborative cooperation means that the special constellations of actors and different perspectives could be bundled [70]. The single innovation processes could, thus, be legitimized by the encouragement of stakeholders, beneficiaries, and the general public. In the experimental testing it became clear that the specific social needs (e.g., of citizens) are of particular importance as a starting point for innovation processes.

Similar results have also been shown in Dortmund. Municipal innovation labs need trust and support by citizens and organised civil society actors, as well as a robust mandate is needed for the intended processes. The results of these innovation processes, in turn, require a socially innovative environment in which ideas can be further developed and spread in an urban society. This requires municipal infrastructures and reliable institu-

tionalization. This also includes the necessary support for collaborative work processes through appropriate methodological skills. It can also be said that municipal innovation processes that are geared towards socially innovative initiatives create new learning and participation opportunities. Even if this cannot replace administrative decisions and even only partially change them, spaces for experimentation can still arise, through which actors can bring in new perspectives to the urban discourse on specific challenges [52].

As part of the three-year national project support, some opportunities and challenges with regard to reflection, networking, and knowledge transfer were identified. The main result of the real-world experiments is that both cities have succeeded in establishing a corresponding municipal infrastructure for "spaces of collaboration". The scientific supervision gave space for discussion and the structuring of lessons learned. It focussed on the status of the project implementation and the strategic objectives of the project. A special focus of the supervision was on the cooperation between science and practice in the context of a transdisciplinary research project. Each supervision was documented in the form of a detailed protocol, which was jointly approved among the participants. The findings were evaluated in a contrasting manner and presented to the project group in order to then jointly discuss the results. In this way, an early transfer of results was ensured and local learning processes were supported [43].

Based on this, several lessons were identified. For example, a transdisciplinary project needs critical accompanying research that reflects the implementation processes from a more "neutral" perspective and provides advice for optimization and readjustment in the course of the project. This kind of reflection supported by a research unit not involved in the actual living labs was also implemented in Evolving Regions, but was absent in the other projects. In iResilience, a systematic monitoring was put in place, but this was handled by researchers also involved in the transdisciplinary processes. By means of such reflections, all participants had to critically reflect on their own role. Thus, an understanding of the action of one's own and the other participants' action emerged. External support for supervision is helpful in order to enable a critical view from the outside and to support a non-biased moderation and facilitation. Supervision should take place regularly. Overall, a process of reflection is manageable and useful to continuously adapt the course of the project. Proper documentation is necessary in order to make agreed positions and measures verifiable in the further course of the process.

A targeted innovation policy is necessary for the development of sustainable municipalities. It is an essential part of enabling municipalities to embark on a path of transformation. This form of qualification is discussed under the keywords transformative literacy and (urban) transformative capacity [71,72]. It is about enabling learning environments through which sustainability transformations can be initiated and disseminated. Research institutions play a special role here because they have interdisciplinary expertise and are integrated into a wide range of knowledge spaces [72,73]. The creation of diverse spaces for discourse in cities as part of transformative governance is necessary, whereby the transformative effect of civil society, as well as municipal activities can be strengthened by linking them to scientific expertise [73]. Knowledge about the development and successful implementation of transdisciplinary research projects is growing and it is becoming increasingly easier for interested scientists to access knowledge about a successful combination of research and practice designs in such project contexts [51,74].

3.2. ProPolis

The framework for the transdisciplinary collaboration in ProPolis was to a large extent predetermined by the funding measure, which predefined three separate modules. This caused limitations with regard to the transdisciplinary integration. ProPolis provided a bridge between science and practice, but real integration was challenging, due to the fact that the modules operated in parallel, and were only to a limited extent integrative. Nevertheless, prospective end-users took an indirect influence on the development of PALM-4U, and therewith supported the development of a tool that is applicable in practice,

and thus, has the potential to lead to applicable innovation. During the first funding phase, the practice partners were asked to formulate requirements towards the new urban climate model. The flow of information was rather directed from the practice partners towards the model developers, while Module C acted as a translator between the users and model developers. The aim was to tailor the model development to diagnose needs at an early stage. The interaction between the users and model developers was, therefore, indirect. In the second phase, the focus was on bringing the model into a long-lasting operational service. In this phase, Module C left its role as translator and entered a reciprocal relationship with the practice partners. The flow of information was primarily directed from ProPolis towards the practice partners (see also [60]). The practice partners were asked to assess and share their experiences and opinions.

Practice partners (i.e., prospective users within municipalities) essentially only collaborated with the scientific partners within Module C project ProPolis. As such, one cannot really speak of co-production of knowledge and of truly participatory transdisciplinarity in the development of the PALM-4U urban climate model. Given the complexity of the model development, this choice, made in the design of the funding structure, may be justified. On the other hand, halfway through the second funding phase, a noticeable shift in perception among several members of the Modules A and B could be observed. Due to its focus on non-scientific users, Module C, for instance, pushed for the development of an attractive and easy-to-use GUI (graphical user interface). Although this was long seen as being of secondary interest, representatives of Module A and B started to express sincere interest in its development. Without the consulting of the transdisciplinary set-up of the entire project, it seems doubtful whether a GUI would have been included in the model's development at all.

The entire funding measure covered a broad spectrum of stakeholders during the research and development phase of PALM-4U. Different types of knowledge, therefore, flew into the development of the new urban climate model. Reflecting from the position of social scientists aiming to integrate the user perspective, this process was at times somewhat frustrating. There still is a substantial gap between the scientific development of this state-of-the-art tool and the everyday practice of creating urban development plans. Whereas scientific model developers sometimes did not seem to realize the constraints of the working practices within a municipality, practitioners regularly expressed totally unrealistic expectations towards the model. Would a more integrative collaboration between science and practice have helped to overcome these challenges? Perhaps. This would have been a very time-consuming journey though, in which the expectations and experiences were very far apart. Even though the current process also took multiple years, the model developers could focus their attention almost exclusively on the PALM-4U development, while both scientists and practitioners were slowly introduced to each other's viewpoints. Nowotny, cited above ([5]), underlines the need for patience, but in a project that in its current form has already taken over 6 years, one has to acknowledge practical limitations with regard to patience for transdisciplinary collaboration.

ProPolis aimed to maximize its impact by enhancing the uptake of PALM-4U by establishing a community of practice. The CoP is meant to provide mutual learning opportunities among PALM-4U users during the project and after project completion. During the funding phase, the CoP supplemented the project-driven spaces for exchange. After the funding phase, the CoP will ensure further mutual support, mutual learning and might give incentives for further practical development of PALM-4U. A substantial challenge hovering over the project is the sustainable continuation of the CoP. The ending of research funding is a common threat to transdisciplinary research projects (cf. [75]). In KoSI-Lab, communal structures could be build up to continue along the lines of the project, and first signs of (partial) continuation in iResilience could be witnessed in summer 2022. A CoP needs an intrinsic motivation in order to be sustained, and needs a certain governance structure [76], the PALM-4U user community, this will initially be carried by the Climate Service Center Germany. In the long run, it is uncertain how this CoP will develop. This lack of certainty about the long-term impacts and continuity of transdisciplinary projects

frustrates the results of the work performed by scientists engaged in transdisciplinary endeavours which, as commented above, has taken a lot of time already.

3.3. iResilience

Throughout the course of iResilience, civil society stakeholders were supported by the project consortium to independently raise resources and build up capacity. New formats of cooperation between the different stakeholder groups promoted the process of co-creation. The support and involvement of the local administration of the cities of Dortmund and Cologne was central in this process as it opened up new modes of governance and enabled a new and strengthened exchange of knowledge, resources, and concerns between politics and civil society. Nevertheless, the process also made visible potential frictions between innovative initiatives and existing structures.

One point of friction, for example, came to fore in the complex situation the colleagues working within the cities found themselves in because the research project and the city administrations are driven by different logics. The individuals employed by the city partners in the project had to navigate between the experimental nature of a research project and the structured and planned hierarchies of the administrations they work in. They collaborated with the stakeholders in the living labs according to governance principles with no hierarchies (after, e.g., [58]), but then had to translate and transfer the results into their organisations, in which they still had to deal with existing hierarchies. It is important to address this role conflict and to clarify the role of the individuals as project members. This complex structure, in return, despite the best intentions of the cities and their staff, can lead to irritation among citizens and a lack of belief in the possibilities and reach of their work in the living labs. It was in this field of tensions that the project, by means of experimental methods and approaches, had to operate to, one step at a time, implement new approaches for knowledge co-creation.

As transdisciplinary projects ought to be critical and self-reflexive [29], not only the outcome, but also the process was evaluated through interviews, focus groups interviews, and questionnaires for participants, as well as through internal team reflection meetings. A total of 21 people from the administrations of both cities, local initiatives, residents and professionals (e.g., teachers at a school) were interviewed. The participants describe their work in the format as successful, and they described being satisfied with the cooperation among themselves. As one participant expressed it: "I didn't feel as if I was just an employee of X department, but as someone who can provide positive input regarding operational processes or can point out options based on my professional knowledge" quoted in [55] (p. 84).

Nevertheless, the outcomes of the project show mixed results, which concern both citizen engagement, as well as the possibilities of real co-creation of climate change adaptation measures and strategies. In certain neighbourhoods it was easier to reach and activate stakeholders than in others. Interest in engaging with transdisciplinary research projects was often restricted. On the other hand, it must also be concluded that setting up participatory living labs engaging all quadruple helix stakeholders simply took time and several measures could eventually be implemented. Examples include the setting up of a network of engaged elderly that support each other with information on how to deal with extreme heat in Cologne [77], the implementation of water tanks that save rain water and enable volunteers to access tap water from water urban green in Dortmund (instead of having to carry tap water from their homes) see [78] (pp. 24–27), and the redevelopment of a street in Cologne, which was vulnerable to flooding due to heavy rain, but that will now be made climate resilient based on the plans developed within an transdisciplinary team of hydrologists, the city of Cologne, its municipal drainage company, landscape planners, and local residents [79].

Reaching the right stakeholders takes time, and so does convincing them of the benefits of participation. In addition, processes within the living labs can take time, which may lead to citizens or other stakeholders becoming impatient. Citizens expect to see the impact quickly. Interfering in the urban landscape, however, is complex, involves many different

departments and involves the weighting of many different interests. Proper expectation management, in combination with solid communication is, therefore, vital.

3.4. Evolving Regions

The Evolving Regions project, with its broad transdisciplinary project consortium, has supported cross-sectoral stakeholder networks within the participating regions to build competences and capacities to develop long-term solutions to the challenges posed by climate change. The partner institutions involved in the regional processes were according to the evolving roadmapping method [68] with their different roles and services to support the local practice partners.

Within each region, relevant actors from various areas of municipal administration, district and local politics, clubs and associations, companies, and research and educational institutions, as well as actors from agriculture, forestry, and nature conservation came together based on three region-specific topic areas. Supported by the project consortium, the regional actors jointly formulated a coordinated vision and mission statement for their respective regions. This set out a vision for the region in 2040. Based on the climate impact analysis carried out by IRPUD, the regional and local impacts in the respective region were examined and hot spots and needs for action were identified. Based on the jointly developed vision and with the help of the identified climate change impacts, the actors in the regions jointly developed climate adaptation measures within the selected thematic fields. These were, for example, agriculture and forestry, climate-resilient urban development or climate-sensitive species and habitats. Approximately 25 climate adaptation measures were developed per region, containing corresponding individual measures and implementation steps in order to prepare the implementation of the measures as well as possible. In addition, project partner Prognos AG carried out impact assessments of the developed measures in order to be able to prioritise them on this basis. In addition, indicators were developed for each measure, which can be used to estimate the effectiveness of a measure.

The established transdisciplinary and regional networks within the regions are a success factor for the development of targeted measures, and are important for the consolidation of the structures established in the process and for the implementation of the developed measures. Within the roadmaps, this was identified and recorded as an important further need for action [80]. As stated by the Chief District Administrator of the district of Soest the collaborative process "laid important foundations, both regarding advancing scientific knowledge and regarding the implementation of measures" (in [81]). The district of Minden-Lübbecke, for example, has already continued the network independently and implemented the first measure from the roadmap by holding a first meeting on the "Round Table on Climate Impacts" within the district of Minden-Lübbecke [80]. The roadmaps have been politically adopted in all regions, so that they can serve as a basis for regional climate adaptation, even beyond the project duration, and implementation can be advanced. An important factor for success and the necessary political backing was the involvement of representatives from the working level, as well as from the decision-making level.

The transdisciplinary work within the project and the support in the regional processes have led to a total of more than 620 different actors participating in regional processes in the seven participating regions and working together. A transdisciplinary approach means that a broad range of different actors with diverse interests, objectives, and prior knowledge come together. The vision-guided evolving roadmapping method made it possible to establish a common basis for communication and to identify different interests that can arise when, for example, conflict issues such as land use arise in the field of agriculture.

The processes the stakeholders jointly went through, contributed to an exchange and a mutual generation of knowledge, and led to 'personal learning processes' taking place among the participants. Schneider et al. [19] (p. 31) assume "that when potential change agents engage in TD [transdisciplinary] work including joint experimentation, learning, and self-reflection, they develop competences (knowledge, skills, values, and attitudes) that enable them to better tackle sustainability challenges and opportunities in their life

and work". Through the different partner institutions that act as enablers in the regions, competences and network structures were built up, which led to the complete adaptation cycle not only being arranged top-down, but also being supported by the stakeholders, i.e., in a bottom-up way.

4. Results—Qualitative Analysis of Transdisciplinary Research

This paper described four transdisciplinary projects. For each project, we analysed opportunities and challenges for transdisciplinary research. These project experiences were analysed in team meetings reflecting on the processes and on our roles as social scientists in transdisciplinary projects. This section draws lessons as experienced from within.

As mentioned above, the continuity of projects is a challenge [75], especially when university actors lead these projects and are dependent on external funding. However, transdisciplinary collaborations can also be an opportunity for continuation. As externally funded scientists—and crucially important in collaboration with institutional partners such as our municipal or district partners—it became possible to set up and kick-start projects that contribute to (urban) innovation. Thanks to the engagement of other stakeholder groups, the researchers were in a better position to generate applicable knowledge (i.e., the ontological logic) and innovation (i.e., the logic of innovation), and the research found broader legitimation (i.e., the logic of accountability [4]). A fourth logic of interdisciplinarity can be added to Barry et al.'s [4] thoughts: a logic of empowerment. Transdisciplinary collaboration empowers researchers to not only 'discover' innovations, i.e., to invent, but also to implement, i.e., to innovate. However, especially in the realm of social innovations and climate change adaptation, the absence of a market-logic to further develop the innovations, requires a logic of empowerment that motivates researchers to engage in (time-consuming, let us not forget) transdisciplinary collaboration.

KoSI-Lab achieved impact through the establishment of municipal infrastructures for "spaces of collaboration". Within iResilience, several initiatives that were developed within the project have materialized into sustained practices, and local stakeholders have expressed willingness to carry on to further develop and implement project results (for instance, by the climate resilient remodelling of a vulnerable street in Cologne (see [80])). Within ProPolis, the involvement of non-academic partners was empowering for the social scientists in the sense that it strengthened them in convincing the scientific partners in Module A and B to develop a GUI to make the application of the model more intuitive. In Evolving Regions, finally, the regions have completed their roadmap towards climate resilience (e.g., [80,81]). The actual implementation of the steps is beyond the reach of the project, but the concrete intention expressed by local stakeholders to implement measures beyond the duration of the funding period again empowers researchers in generating real-world impacts. With the Evolving Region project ending, 38 local actors from the district of Soest, for instance, pledged to support the actual implementation of the developed measures over the coming years [80].

Transdisciplinary research provides opportunities for scientists through the logic of empowerment. On the other hand, some barriers must be acknowledged.

Transdisciplinary collaboration almost by definition involves conflicts with regard to goals and expectations [18]. Borup et al. [82] present a rather optimistic view of the role of expectations in the development of science and technology. On a macro-level and in the proposal phases, the experiences made in these four projects underline this. Overall, the goals and expectations of project partners usually align sufficiently to initiate a project proposal, but they are also still vague enough for everyone to develop their own expectations without resulting into visible conflicts yet. Once the details of the processes are developed and implemented, differences in expectations come to the fore and conflicts may emerge. Conflicts need not be a bad thing, but they have to be managed well.

At least four different types of conflicts could be derived from these projects. Firstly, conflicts can emerge within the project team with regard to expectations and roles. Scientific partners may have different expectations and goals than practice partners. The alignment

of research interests and (short-term) societal impact can be challenging (see also [15]). In iResilience, for instance, the municipal project partners were expected by citizens and politicians to produce visible results. For the scientific partners, this was only a secondary objective, as the novel participation formats were central to the analysis. These two goals can go hand in hand, but the careful planning of the process slowed down the actual implementation. KoSI-Lab built up a structure for successfully managing expectations through the regular joint evaluation of the project.

Secondly, conflicts may emerge between the project and expectations of external stakeholders. When engaging non-experts in the co-production of knowledge, it is important to manage expectations and to communicate the limitations of the project (whether legal, technical, financial or administrative). Citizens are often not aware of these limitations and may develop exciting new ideas, only to learn that they cannot be implemented later, for instance, because of legal barriers. In an ideal scenario, relevant experts are directly involved and can discuss these limitations with other stakeholders; in practice, it is usually impossible to bring all necessary expertise to the table. An example of this type of conflicts could be witnessed within ProPolis. Certain wishes of prospective users, such as quick computing and easy tinkering are simply not feasible within the PALM-4U model. In such cases, good communication and expectation management is vital.

Thirdly, conflicts may arise concerning the weighing of impact factors, e.g., should environmental concerns be placed above social issues? Should urban green be removed in favour of more housing, for instance. Or is it acceptable to remove parking opportunities in front of shops and replace them with trees? This is a common challenge for sustainability transitions that need to balance social, economic, and environmental goals. The transdisciplinary approach offers advantages to address these conflicts by bringing all stakeholders to the table. At the same time though, there is a risk of slowing down the process and, in as far as consensus can be reached, this may lead to incremental rather than more radical changes.

Finally, role conflicts may emerge within the individual project employees. This could be observed in iResilience, in which the people working for the municipal project partners had to balance their role as project moderators and city employees. Differentiating between these roles is difficult enough, but becomes even more challenging in participatory settings in which citizens and other stakeholders are not able to distinguish these roles. Citizens, for instance, used project meetings to address specific challenges they had with the local administration, for instance, regarding rainwater drainage and expected the project employees to deal with them, whereas their assignment was not to look into specific cases, but to address the problem of climate resilience in the neighbourhoods more generally.

5. Conclusions—A Logic of Empowerment

There is an increasing trend towards transdisciplinary research projects that emerged in the 1990s with Mode-2 science [6,9] and developed into quadruple helix [38] and living lab [15,16,26] approaches in which non-scientists and civil society actors collaborate on equal terms with academic researchers. As transdisciplinary research ought to be "critical and self-reflexive" [29] (p. 8), lessons were continuously derived within the project internal evaluations, as well as in cross-project analyses. Various challenges and opportunities for transdisciplinary work could be extracted and were presented in Section 4. In order to answer the third and final research question—what is the rationale for engaging in transdisciplinary research from the perspective of social scientists?—we build on Barry et al.'s [4] logics of interdisciplinarity. Although the logic of accountability might be less present—though not absent—within the individual researcher and rather applies to notions of the entrepreneurial university at a more strategic level, the analysis did bring to the fore the logic of innovation and ontological change. Supplementing Barry et al. [4], a logic of empowerment was identified among the researchers within the projects. Analysing quadruple helix collaborations from within, it must be acknowledged that rather than a drive for accountability, researchers engage in transdisciplinary collaboration out of a drive for empowerment regarding the actual development and implementation of project

outcomes. Non-academic stakeholders tend to be in a much better position to implement (urban) innovations (i.e., municipal actors), and—crucially—oftentimes are much better equipped to continue beyond the project lifetime. Academic research projects are restricted by project funding (cf. [75]). Once the funding dries out, like nomads, researchers move on to the next funded project. The actual implementation of project 'inventions' oftentimes has to take place beyond the project lifetime and is dependent of non-academic stakeholders. These stakeholders therewith not only contribute to the innovation making (i.e., the logic of innovation), but also to the innovation implementation, therewith empowering researchers to enlarge the impact of their work.

Besides the logic of empowerment as motivator for transdisciplinary collaborations, four types of conflicts that are likely to emerge in transdisciplinary projects were identified in Section 4. Central to overcoming these conflicts are communication, trust, and openness. All participants in transdisciplinary projects need to be open to learn from others. This means that they need to accept criticism and need to be open to the idea of doing things differently. Changing existing routines and views can be hard, but if participants are not open to different views or approaches, collaboration will be hampered. As a consequence, flexibility within the project design is vital (cf. [42]).

Listing communication as key for transdisciplinary collaboration may be an open door. However, it is not at all trivial. Experience shows, there is not always willingness to communicate with other stakeholders. Likewise, jargon may hamper effective communication. When software developers speak of an operational climate model, for instance, they have completely different expectations than the 'lay' users that are project practice partners and, more importantly, targeted end-users.

With proper communication and sufficient openness, trust can emerge. Trust needs to develop. In this respect, not only communication is necessary, but also time (cf. [5]). Optimistically conceived project proposals may overlook the importance of time to develop an effective work environment for transdisciplinary projects. This, again, can lead to conflicts because of unmet, or too slowly fulfilled, expectations. An important lesson for transdisciplinary research is to allow sufficient time to build up an atmosphere of collaboration based on mutual understanding and trust.

In relation to time, transdisciplinary projects can benefit from building a protective space for experimentation, with space for failure. Space for experimentation and failure is crucial, as it creates an environment in which trust between actors can be build up. This can stand in conflict with a drive to create impact though. Especially in projects in which public actors are involved, quick results may be expected.

By analysing experiences across four different project, broader and more general conclusions could be drawn than what would have been possible within the individual projects. This paper also adds to the existing literature by presenting an analysis from within, i.e., by social scientists who took part in the transdisciplinary projects. Its findings imply a need for transdisciplinary research projects to not only engage quadruple helix stakeholders within research projects, but to actively make sure to include powerful actors, i.e., those who have the ability to really apply project findings after the funding period. The chances of actually implementing urban climate change adaption measures, for instance, increase if local public administrations are actively part of the research project. This empowers those who engaged in the transdisciplinary collaborations.

Finally, it must be acknowledged that the fact that the authors were part of the projects also presents a limitation of the research in the sense that the availability of projects for the analysis was restricted to the projects within which the authors were themselves involved. Future studies analysing drivers, opportunities, and barriers of transdisciplinary research projects will have to confirm the presence of a logic of empowerment as a driving logic of inter- or transdisciplinarity among other researchers by more specifically than has hitherto been the case, focusing on the role and experiences of (social) scientists in transdisciplinary research projects.

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