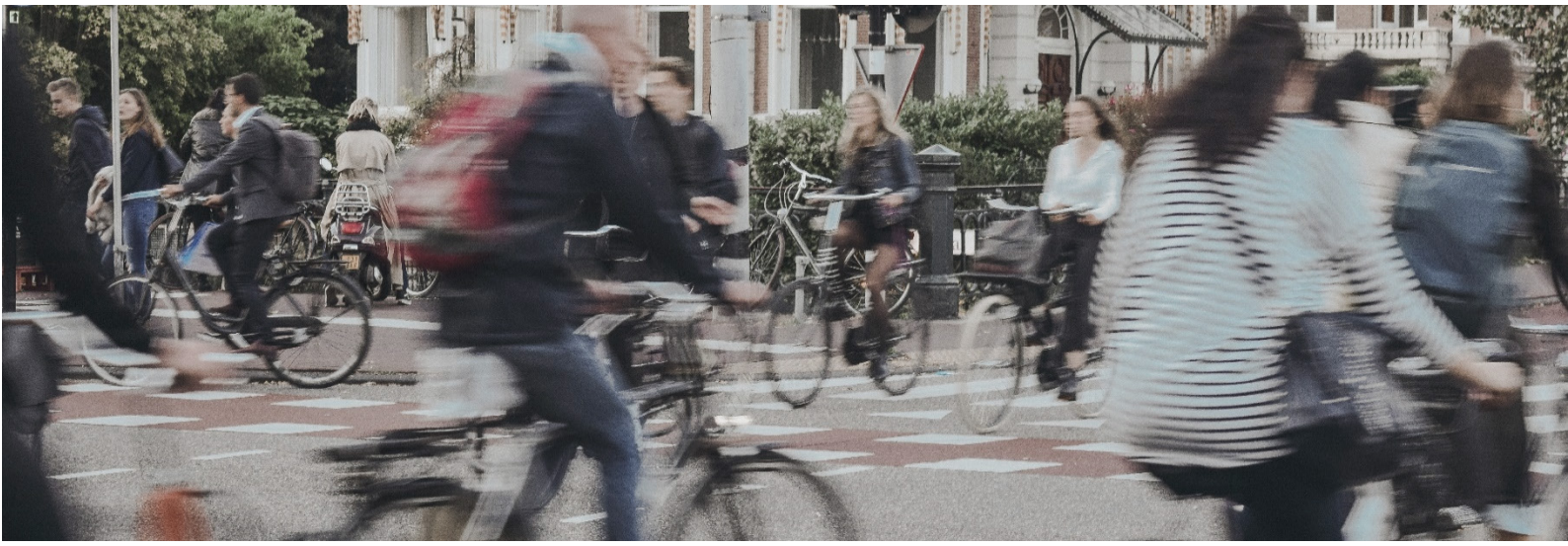

TdLab Geographie – Discussion Paper No. 1

HOW TRANSDISCIPLINARY PROJECTS CAN CONTRIBUTE TO CLIMATE-FRIENDLY MOBILITY IN CITIES

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Declaration

This publication is part of a series of discussion papers by the TdLab Geographie team at Heidelberg University. Within the series, current research results are made available to the public.
The publication is based on a bachelor's thesis dealing with sustainable mobility. The results of the thesis were further processed by the TdLab Geographie team.

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Author contributions

K. F. wrote the manuscript. The concept of the study was co-designed by N. A. and K. V.
K. V. is the author of the original thesis and supported the team in preparing the study for publication.
S. E. assisted with the preparation of the initial draft for the manuscript.

ABSTRACT

Cities play a key role in anthropogenic climate change, as they emit high amounts of greenhouse gases due to their infrastructures and large number of inhabitants. On the other hand, they hold massive potential for contributions to climate change mitigation and adaptation, which has not yet been fully exploited. The mobility sector plays a decisive role in this. In this study, we examine and compare several transdisciplinary projects (including real-world laboratories) in regards to their potential impact on the development of sustainable mobility alternatives in cities. The aim is to identify and highlight advantages of transdisciplinary research in this context compared to research projects, that do not include participative components and to specify framework conditions for its successful implementation. Transdisciplinary research approaches that include the expertise of local stakeholders can provide necessary practical requirements and feasible concepts, which make success much more likely and facilitate implementation. However, the success of transdisciplinary studies depends on a variety of factors that determine the outcome and impact of these projects. This also raises the question of how success of a project can be defined. Therefore, we studied three transdisciplinary projects focussing on urban sustainable mobility in different cities in Germany. Two of them were also evaluated in Bergmann et al. 2021 with regard to their success factors. A series of expert interviews with participants of the above-mentioned projects was conducted and evaluated. Success factors of transdisciplinary settings include communication at eye level between all participants, measurability of the impact of different activities, and the incorporation of concepts for continuation. Challenges consider mainly the voluntary commitment of involved actors and short time frames for implementation. The results show that transdisciplinary approaches can support climate-friendly mobility by raising awareness and demonstrating sustainable transformations through best-practice examples, especially in the local context. Furthermore, transdisciplinary approaches can be seen as role models for climate change mitigation in cities and viable mobility alternatives. It is recommended to support networking and cooperation between transdisciplinary projects in order to further explore the challenges and success factors, and thus strengthen the transdisciplinary format and achieve a broader impact.

Städte nehmen eine Schlüsselrolle ein im Kontext des anthropogenen Klimawandels, da sie aufgrund ihrer Infrastruktur und Einwohnerzahlen große Mengen an Treibhausgasemissionen verursachen. Andererseits können Städte ein enormes Potenzial für Beiträge zum Klimaschutz und zur Anpassung an den Klimawandel entfalten, das bisher nicht voll ausgeschöpft wird. Der Mobilitätssektor spielt dabei eine entscheidende Rolle. In dieser Studie untersuchen und vergleichen wir mehrere transdisziplinäre Projekte (darunter auch Reallabore) im Hinblick auf ihren potenziellen Einfluss auf die Entwicklung nachhaltiger Mobilitätsalternativen in Städten. Ziel ist es, die Vorteile transdisziplinärer Forschung in diesem Kontext im Vergleich zu Forschungsprojekten, die keine partizipativen Komponenten beinhalten, zu identifizieren und die Rahmenbedingungen für ihre erfolgreiche Umsetzung zu spezifizieren. Transdisziplinäre Forschungsansätze, die das Wissen und die Perspektiven lokaler (Praxis-)Akteure einbeziehen, können notwendige praktische Anforderungen und umsetzbare Konzepte liefern, die den Erfolg und die Umsetzung wesentlich erleichtern. Der Erfolg von transdisziplinären Studien hängt jedoch von einer Vielzahl von Faktoren ab, die das Ergebnis und die Wirkung dieser Projekte beeinflussen. Dies wirft die Frage auf, wie der Erfolg eines Projekts definiert und gemessen werden kann. Daher haben wir drei transdisziplinäre Projekte mit dem Schwerpunkt auf nachhaltiger Mobilität in verschiedenen Städten in Deutschland untersucht. Zwei davon wurden auch in Bergmann et al. 2021 im Hinblick auf ihre Erfolgsfaktoren evaluiert. Es wurde eine Reihe von Experteninterviews mit Teilnehmer:innen der drei untersuchten Projekte durchgeführt und ausgewertet.
Zu den Erfolgsfaktoren transdisziplinärer Settings gehören die Kommunikation auf Augenhöhe zwischen allen Beteiligten, die Messbarkeit der Wirkung verschiedener Aktivitäten und die Einbindung von Konzepten zur Verstetigung. Als Herausforderungen gelten vor allem das freiwillige Engagement der beteiligten Akteure und kurze Zeiträume für die Umsetzung. Die Ergebnisse zeigen, dass transdisziplinäre Ansätze eine klimafreundliche Mobilität unterstützen können, indem sie das Bewusstsein fördern und nachhaltige Veränderungen durch Best-Practice-Beispiele vorantreiben, insbesondere im lokalen Kontext. Darüber hinaus können transdisziplinäre Ansätze als Vorreiter für den Klimaschutz-Projekte in Städten und tragfähige Mobilitätsalternativen angesehen werden. Es wird empfohlen, die Vernetzung und Zusammenarbeit zwischen transdisziplinären Projekten zu unterstützen, um die Herausforderungen und Erfolgsfaktoren weiter zu erforschen und so das transdisziplinäre Format zu stärken und eine breitere Wirkung zu erzielen.

1 INTRODUCTION

Climate-friendly mobility is a mechanism for climate change mitigation (Foltýnová et al. 2020; Bardal et al. 2020; Acheampong et al. 2021). Especially in cities and large metropolitan areas, there is an increased demand for various (sustainable) modes of transportation (Bulkeley 2010; Rosenzweig et al. 2015). In this context, motorised individual traffic continues to play a major role (Gössling 2020). Inner-city mobility in combination with commuter traffic often leads to congestion, air pollution (exceeding the limit values for a particulate matter) and high greenhouse gas emissions (Gössling 2020; Weiand et al. 2019; Creutzig et al. 2012). There is a multitude of concepts and projects to establish sustainable mobility alternatives; but the strategies, success of implementation, and progress in establishing sustainable transport varies among cities and nations (Norström et al. 2020; Foltýnová et al. 2020). The findings of Foltýnováa et al. suggest that even stakeholders who have the same definition of sustainable urban mobility can deviate significantly in their ideas of how to achieve their goals. There is still a large gap between the theory of sustainable mobility and its implementation in practice (Foltýnová et al. 2020). To close this gap and to create practice-oriented solutions based on scientific findings, transdisciplinary approaches have become more and more important in recent years.(Stinder et al. 2022; Fernandez-Heredia and Fernandez-Sanchez 2020). To this end, stakeholders, such as citizens, city authorities, companies and interest groups, are involved in the planning and development of innovative mobility concepts. For this, (political and societal) frameworks and platforms need to be formed to integrate the different perspectives and jointly develop the design and infrastructure of urban transport (Acheampong et al. 2021; Bardal et al. 2020; Fernandez-Heredia and Fernandez-Sanchez 2020).

2 STATE OF THE ART

A multitude of disciplines (natural sciences, social sciences, behavioural sciences, humanities, medicine and many more) are concerned with the various aspects of climate change. Climate change research provides detailed insights and solid facts about the causes and impacts of current global warming (Schneidewind 2018; IPCC 2018; United Nations 2015; Rockström et al. 2009; Schellnhuber 2009; McCarthy et al. 2010; IPCC 2013). The challenge of climate change in particular has shown that disciplinary approaches limited to scientific actors are not effective enough, as they ignore relevant practical knowledge, do not adequately reflect the realities of a society, and thus cannot develop sufficient motivation among stakeholders (Norström et al. 2020; Fernandez-Heredia and Fernandez-Sanchez 2020; Lang et al. 2012; Pohl 2008; Pohl et al. 2017; Pohl et al. 2021).

2.1 TRANSDISCIPLINARY APPROACHES

Stakeholders can take on different functions and roles in the participation process: They contribute ideas, define requirements, communicate practical capabilities and challenges, or serve as test users. Their expertise and participation (co-design and co-creation) complement the scientific approach and expand the wealth of experience of transdisciplinary research in general. This also strengthens the role of non-scientific actors in the research context. Thus, from the very beginning of a project, they are indispensable for a citizen-centered implementation of mitigation and adaptation concepts (Fernandez-Heredia and Fernandez-Sanchez 2020; Norström et al. 2020; Fox-Kämper et al. 2020; Baum et al. 2020; Schaufler and Staffa 2020). At the same time, integration into the research process raises awareness of the need for climate change mitigation and adaptation measures (Steynor et al. 2020).

Our paper focusses on a physical-geographical perspective on climate change mitigation exemplified by climate-friendly mobility in cities. We see the cross-methodological, cross-thematic and cross-institutional approach of transformative or transdisciplinary research as the most important way to address major societal challenges we are facing, so-called "wicked problems", and to co-create possible solutions (Aeschbach and Foshag 2019; Adler et al. 2018; OECD 2020; Stinder et al. 2022).

Under the title "Closing the Knowledge-Action Gap in Climate Change", Knutti reflects on why scientific knowledge is not matched by an equally significant increase in climate mitigation and adaptation efforts (Knutti 2019). Knutti suggests that data output from climate research should be more clearly aligned with actionable, user-oriented information (e.g. local data, impact data, adaptation data, technologies, extreme events, composite events) and that stakeholders should be consistently involved in projects (Knutti 2019). This leads to inter- and transdisciplinary approaches that cross fields and involve local "non-scientific" actors (Moallemi et al. 2020). Alongside interdisciplinarity, the concept of transdisciplinarity is increasingly coming to the fore in order to address the complexity of the current challenge (Bammer et al. 2020). Both in climate change research and in other fields of application, transdisciplinarity can be explicitly or implicitly included. Various science policy discourses, e.g. on the "Grand Societal Challenges" (WBGU 2011) call for the development of a novel, science-based transdisciplinary methodology. Transdisciplinary research aims at solving complex societal problems and advancing scientific knowledge. The challenge is to combine scientific innovation and excellence with a practical and application-oriented approach. This can be counterintuitive, but also enables a new dimension of scientific outcomes. However, this requires a novel understanding and adapted methodology in transdisciplinary research (Adler et al. 2018; Lux et al. 2019; Lux et al. 2020; Schneidewind 2016; OECD 2020).
In our paper published in 2020, we presented an integrated transdisciplinary set of methods to co-design climate change adaptation measures in cities. The design captures the complexity of real-world as well as scientific problems, while considering the diversity of perspectives. By combining and integrating different knowledge stocks, concepts can be developed that facilitate solution approaches to major societal challenges at the interface between science and society (Foshag et al. 2020; Lang et al. 2012; Pohl 2008). The aim is to identify effective and "publicly accepted" solutions to make measures more feasible (Adler et al. 2018; Foshag et al. 2020; Pohl et al. 2017; Schneider et al. 2021; Laukkonen et al. 2009; Pohl 2011).
The basic goals and results of transdisciplinary projects are diverse and affect a multitude of topics. The results can function as impulses for stakeholders to promote climate protection or adaptation to climate change. For example, the collection of data can provide new information and bases for measures in cities. Planning offices and city administrations, among others, can be supported by science and transdisciplinary research approaches through the development of effective concepts and practicable solutions.
This understanding and perspective contributes to bridging the gap between knowledge and action at the individual, social, political and economic level. Ideally, an expansion of system knowledge is generated by target and transformation knowledge (Kollmuss and Agyeman 2010; Adler et al. 2018; Knutti 2019; Schneider and Buser 2018; O'Connor et al. 2000).

2.2. CLIMATE FRIENDLY MOBILITY AS ONE OF THE MAJOR CHALLENGES

Mobility is indispensable in today's society. It promotes the economic development of a country and guarantees the participation of the population in social and professional life (Bundesministerium für Bildung und Forschung 2018; Stinder et al. 2022). However, the increase in traffic brings many disadvantages for people and the environment due to harmful greenhouse gas emissions, land sealing, land consumption, noise, and contribution to global warming (Jacoby

and Wappelhorst 2016). Since 1960, passenger and freight traffic volumes have quadrupled (Bundesministerium für Umwelt, Naturschutz und nukleare Sicherheit 2019). The continuously high greenhouse gas emissions in the transport sector also reflects this trend, despite efficiency improvements in this sector. In 2020, emissions have fallen by 11.1% compared to the base year 1990. However, these reductions can be traced back to the COVID-19-Pandemic and are most likely temporary. This trend is also reflected in the increase in greenhouse gas emissions in other years: in 2017, 167 million tonnes more CO_2 equivalents were emitted in the transport sector than in the reference year 1990 (Bundesministerium für Umwelt et al. 2021).
With 20 %, the transport sector is responsible for the third largest part of emissions of greenhouse gases in Germany. Motorised road traffic accounts for the largest share of these emissions at approx. 96 % Of these, passenger car traffic contributes 61 per cent (Bundesministerium für Umwelt et al. 2021; Bundesministerium für Umwelt, Naturschutz und nukleare Sicherheit 2016).
Anthropogenic climate change makes it even more important to reduce greenhouse gas emissions in the transport sector and support sustainable mobility (Jacoby and Wappelhorst 2016). According to the Baden-Württemberg Ministry of Transport and Infrastructure, sustainable mobility means, "that today's mobility needs are guaranteed in the future in an environmentally compatible manner. This applies to people and the economy. In addition, the access to mobility of disadvantaged population groups must be further improved" (Bundesministerium für Verkehr und digitale Infrastruktur 2015).
The IPCC Special Report of 2018 and the IPCC Report of 2022 also emphasise that urban system transitions with emission reductions in the transport sector are needed to limit global warming below 2°C resp. 1.5°C (IPCC 2018, 2022). In addition to climate change, one other benefit of mitigating greenhouse gas emissions is the promotion of urban health (United Nations Environment Programme 2019; Gössling 2020). With regard to this, the climate protection target in the German transport sector is to reduce greenhouse gas emissions by 40 to 42 per cent by 2030 compared to the reference year 1990 (Bundesministerium für Umwelt, Naturschutz und nukleare Sicherheit 2016). By 2050, greenhouse gas emissions are to be reduced by 90 % compared to 1990 (Bundesministerium für Umwelt et al. 2021).
Fields of action for climate protection in the transport sector include promoting electric mobility, efficiency regulation of new vehicles, and a shift to climate-friendly modes of transport, such as local public transport, sharing concepts, walking and cycling (Bergk et al. 2017). Furthermore, there is a need for the expansion of sustainable transport infrastructure in cities, such as the modernisation of the railway system to enlarge local public transport and the extension of footpaths and cycle paths (Bundesministerium für Umwelt, Naturschutz und nukleare Sicherheit 2019). Intermodal connectivity and a combination of different mobility services, especially in conurbations, also represent an important step towards sustainable mobility development (Jacoby and Wappelhorst 2016). In addition to these structural measures, a social change in mobility behaviour is needed, as well as intensified public relations work to increase the acceptance of new forms of mobility (Jacoby and Wappelhorst 2016).

3 METHOD

This paper examines how transdisciplinary project designs can contribute to climate protection in cities, especially in the field of sustainable mobility. For this purpose, expert interviews with representatives of selected projects in three cities in Germany were conducted. Qualitative methods of analysis were used to obtain results from the experiences of the projects. These were compared to and supplemented by a literature review.

3.1 QUALITATIVE ANALYSIS THROUGH EXPERT INTERVIEWS

A special feature of the expert interview is the specific target group: the experts. According to Gläser and Laudel (2009), the term "expert" describes the "specific role of the interview partner as a source of specialised knowledge about the social issues to be researched. Expert interviews are a method to tap this knowledge" (Gläser and Laudel 2009). The interviews focus on individuals (experts) representing a point of view, practical and systemic knowledge of a certain group of experts or a professional field (Kruse and Schmieder 2014). Decisive for the expert interview and it´s results is the underlying research question, the purpose of the interview, and the role of the interviewee within the respective project (Gläser and Laudel 2009). In expert interviews, there is a high degree of topic orientation and frequent use of technical language. The communication style tends to be argumentative-discursive. But narrative communication patterns also occur (Kruse and Schmieder 2014).
The guided expert interview was chosen to gather information about the work and processes in the selected projects. Due to the basic knowledge on both sides, interviewer and interviewee held conversations at a high professional level. The guideline ensured that all important information was obtained in a structured way to facilitate the following evaluation.

The interviews were conducted in December 2019. The projects and respective experts were selected according to the following criteria: The research project must be implicitly or explicitly transdisciplinary, the research project is carried out in a city or urban area in Germany, the research project is a real-world laboratory or involves a real-world laboratory, the topic of mobility should be included and the expert is a member of the project team. Following the data collection, the audio recordings of the expert interviews were transcribed, and a qualitative content analysis was carried out to extract relevant information from the raw data. The transcription was conducted using the QDA software MAXQDA, based on the transcription systems of Kuckartz (2014) and Dresing and Pehl (2015) (Kuckartz 2014; Dresing and Pehl 2012).

3.2 SELECTED TRANSDISCIPLINARY PROJECTS

In the research project "KlimaNetze", a joint project of the cities of Bielefeld and Darmstadt in cooperation with the Institute for Regional and Urban Development Research (ILS), two different real-world laboratories were carried out: "Redistributing Transport Spaces" (“Verkehrsräume umverteilen”) and the "Mobility Network Bielefeld (MobiNetz)" (Fox-Kämper et al. 2020). The two other transdisciplinary projects studied are the real world laboratory "Future City Lab – Real world laboratory for sustainable mobility culture” (“Reallabor für nachhaltige Mobilitätskultur") of the University of Stuttgart (Reallabor für nachhaltige Mobilitätskultur, Universität Stuttgart 2020) and “District Future - Laboratory City” ("Quartier Zukunft - Labor Stadt") of the Karlsruhe Institute of Technology (KIT) (Parodi et al. 2020). According to Schneidewind’s definition, two of the three projects operate at the city level, while “District Future - Laboratory City” operates at the district level (Schneidewind 2014).

4 RESULTS

Real-world laboratories and transdisciplinary approaches can contribute to climate-friendly mobility in cities – considering certain factors and processes.

The results show that raising awareness for climate protection, new impulses through “change agents”, and the demonstration of best practices are important aspects for the transformation

towards climate friendly mobility in cities. At the same time, it can be concluded that the mentioned aspects can be initiated by transdisciplinary projects such as real-world laboratories and so-called real-life experiments. Within these activities, impulses for change can be given and approaches to climate protection can be tested on a local scale. Alternative: These activities offer impulses for change and local testing opportunities for approaches to climate protection. Practical experimentation promotes identification with the environment and awareness of alternative ways of using city streets (Baum et al. 2020; Fox-Kämper et al. 2020; Reallabor für nachhaltige Mobilitätskultur, Universität Stuttgart 2020). Possible solutions can be made tangible through transdisciplinary projects and, thus, the urban population can be sensitised to climate change mitigation (Neddermann et al. 2019a; Neddermann et al. 2019b). The safe operating space within the project also presents as a niche. From this niche, impulses and alternative actions can be demonstrated and, thus, a transformation to a sustainable society can be initiated. This is also reflected in the WGBU's main report "Social Contract for a Great Transformation" published in 2011, which emphasises the decisive role of niche actors for the transformation (WBGU 2011).
Nevertheless, the results also show that generally no legislative formulations for climate change mitigation measures and no permanent physical changes to the cityscape result from the transdisciplinary research projects. However, success stories, such as the city committee's decision to apply for funding for the redesign of Wilheminestraße in the real-world laboratorie „Redistributing Transport Spaces“, show that it is feasible to achieve physical changes with the involvement of key stakeholders (Neddermann and Rösener 2022). In this context, the importance of structural preconditions, such as the existing infrastructure, as well as political pressure for climate protection and the change to a sustainable mobility culture, is emphasized (Reallabor für nachhaltige Mobilitätskultur, Universität Stuttgart 2020; Schaufler and Staffa 2020; Bardal et al. 2020). Subsequently, it becomes clear that greater support for transdisciplinary projects is needed, especially from politics (Parodi et al. 2018; Potsdam-Institut für Klimafolgenforschung 2019). Efforts within the framework of transdisciplinary projects alone are not sufficient for a change towards a sustainable mobility culture. This issue, on the other hand, underlines the importance of transdisciplinary cooperation between actors from science and practice, especially from politics, as their involvement is necessary for the implementation of proposed measures (Parodi et al. 2018; Fox-Kämper et al. 2020; Potsdam-Institut für Klimafolgenforschung 2019; Bardal et al. 2020).
Furthermore, it becomes apparent that the manifold effects of transdisciplinary projects are difficult to quantify. A primary goal of climate change mitigation is to reduce greenhouse gas emissions. The results of two expert interviews show that it is challenging to document the emission reductions achieved through the conducted projects. The publication of estimated data, as well as the low scalability of the experiments and their short duration were mentioned as challenges (Parodi et al. 2020). At the household level, quantification is considerably less complicated. Other projects have been able to prove CO_2 reduction through changes in everyday habits based on precise documentation (Potsdam-Institut für Klimafolgenforschung 2019). But again, these are often based on estimated values and not on measured data. In the context of the projects studied, it was argued that qualitative climate change mitigation measures, such as a shift in individual awareness, can have the same impact as quantitative results regarding CO_2 reduction. It should be noted, that recorded emission reduction is beneficial for highlight the impacts of transdisciplinary projects to the public.

Through the cooperation of science and practice, trust in science is strengthened and feasible solutions that would not have arisen in disciplinary work are created. Especially with regard to the complexity of climate change, transdisciplinary work is seen as an appropriate research method. With regard to real-world laboratories, two interviews mention the problem of inflationary increase in the use of this format. Parodi et al. and Schneidewind also point to the ambiguity

of definitions and the associated inflationary use of the title real-world laboratories (Schneidewind 2014; Parodi et al. 2018; Parodi et al. 2019). In particular, the aim of a transformation towards sustainable development is sometimes disregarded (Parodi et al. 2019). Thus, the core characteristics of real-world laboratories need to be further specified and generally accepted definitions need to be identified. This requires further research and, above all, networking of real-world laboratories and transdisciplinary projects. Schäpke et al. also see the stronger (global) networking of real-world laboratories as an opportunity for enabling mutual learning processes and jointly developing solutions for global challenges (Schäpke et al. 2018a; Schäpke et al. 2018b).
The increasing attention to climate change mitigation and adaptation offers the potential for transdisciplinary research formats to increase their relevance. The analysis of the interviews shows that in two of the three projects an increasing interest of the public and demand for events was perceived (Fox-Kämper et al. 2020; Parodi et al. 2018). A possible explanation for the shift in awareness could be the subjective perception of the experts, or a differing regional manifestation of the movement in Germany. However, it can be concluded that the thematic attention can represent a potential for transdisciplinary approaches, which could be utilised, for example, through closer cooperation with initiatives like "Fridays for Future".

The area of influence of the projects and the age structure of the participants depend on the sub-projects and events that are carried out within the projects. In all the projects studied, the stakeholders were described as "highly aware people", "highly interested" or the "green-minded middle". It can be concluded that most of the participants are already sensitised and motivated to engage in climate action (Reallabor für nachhaltige Mobilitätskultur, Universität Stuttgart 2020; Baum et al. 2020; Schaufler and Staffa 2020; Neddermann et al. 2019a; Neddermann et al. 2019b). The interviewed experts state that it may be more effective to work together with already committed citizens and to support them in their engagement, than to aim at the broad population. Without motivated, cooperative, and special people, who are willing to learn, cooperation and success is more difficult (Neddermann and Rösener 2022). Stakeholders who are already active in climate action can thus serve as multipliers in society as a whole (Fig. 1) (Neddermann et al. 2019a; Neddermann et al. 2019b; Reallabor für nachhaltige Mobilitätskultur, Universität Stuttgart 2020; Neddermann and Rösener 2022). Nevertheless, people who are not yet or just slightly aware of climate change mitigation will also be reached more and more frequently. In regard to the examples mentioned in the interviews, it becomes apparent that this is especially related to low-threshold events that operate on the information level (Fig. 1) (Neddermann et al. 2019a; Neddermann et al. 2019b; Fox-Kämper et al. 2020). Examples are “Action days” with specific topics, activities such as clothes swap events or the setting up of “parklets” (temporary or permanent transformed parking spaces into places to stay with seating, greenery, etc.) in the city. Furthermore, it has been shown that those affected by or opposed to these real-life experiments are also being reached, such as residents who criticise the lack of parking space due to the construction of parklets. This can lead to discussions in public or on the street that stimulate a debate about different possibilities of using public space (Fig. 1). In particular, the parklet format seems to be suitable to initiate public and media discussions about the use of public space for transport (Schaufler and Staffa 2020; Parodi et al. 2018).
Furthermore, the age structure of the participants is of interest, as it is important to reach people from different age groups to achieve lasting and profound change. The campaign "Fridays for Future", for example, was initiated by youths and young adults and is often criticized by older people.
The age structure was described as diverse in all three evaluated projects. When interpreting the data, however, it must be borne in mind that these are subjective assessments by the experts. The format of the events and the real-life experiment has a decisive influence on the

age structure of the participants and their participation opportunities (e.g. regarding accessibility, choice of methods, thematic focus, etc.). The incentive provided by training, further education, and the takeover of a specific role and responsibility in the real-life experiment or project can also have an influence on the motivation to act and participate. In two of the three projects studied, the term “pioneers of change” was used, specifically for stakeholders who stand out for their special commitment to climate change mitigation or have a particular intrinsic motivation (Fig. 1). According to the WBGU, pioneers of change, acting as individuals or as groups, are central to the transformation towards a sustainable society (WBGU 2011; Schellnhuber et al. 2016). It is also considered important for a successful cooperation, that the participants are seen as multipliers in order to encourage them to influence their personal environment and thus increase the reach of a transdisciplinary project (Parodi et al. 2018). Leaders and pioneers, e.g. from politics and administration, who actively support the project are also beneficial for the reputation and success of a project (Neddermann and Rösener 2022). In order to extend the reach and positive effects of transdisciplinary projects, the communication of activities and results is another central element. Through (social) media presence, different groups of people are addressed (Fig. 1). Additionally, the literature indicates that public relations work is a central principle to integrate as many people from the population as possible into the real-life experiments and enable them to take climate action (Köglberger et al. 2019; Schaufler and Staffa 2020; Fox-Kämper et al. 2020). Media presence can also trigger social discourse, as mentioned in the example of the parklets (Schaufler and Staffa 2020). A high level of awareness and media presence are particularly advantageous with regard to the continuation of projects and activities.

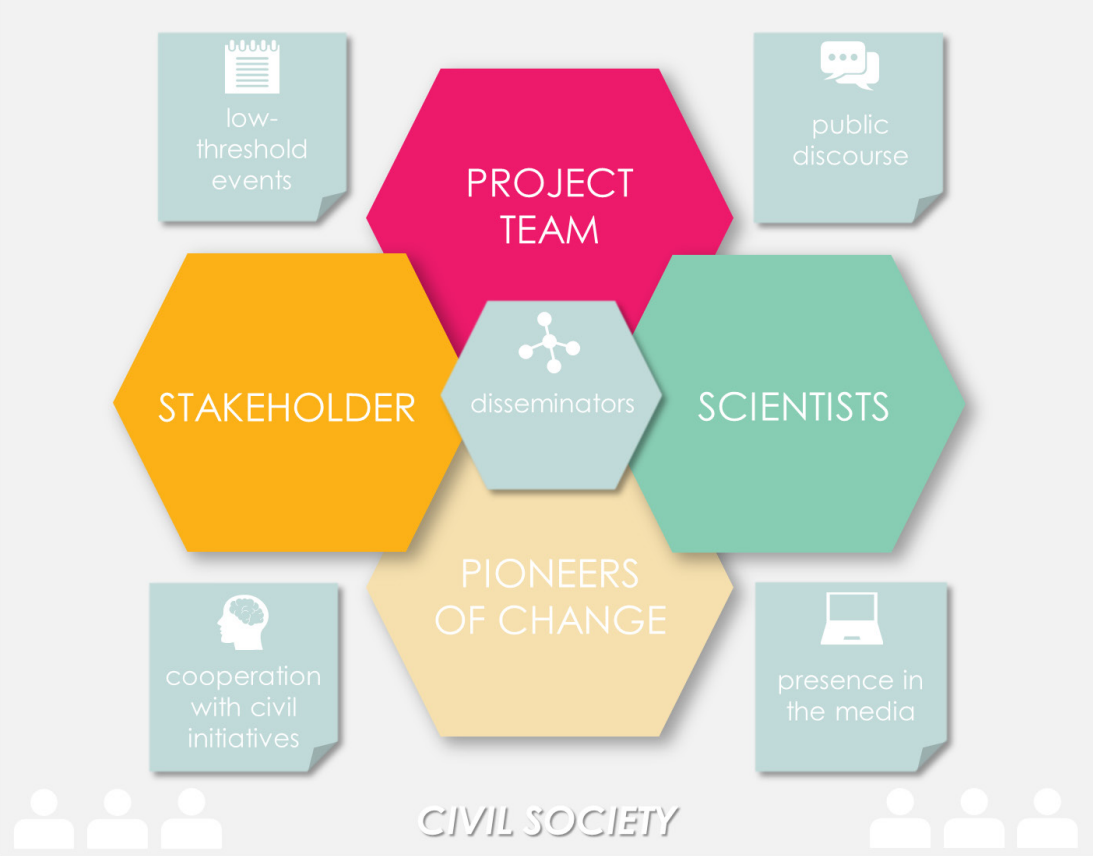

Fig. 1: Graphic representation of the reach of transdisciplinary projects into society. The project team is composed of scientists, mostly climate-sensitive practitioners or respectively stakeholders and pioneers of change. The society and urban population are reached by dissemination activities, low-threshold events, cooperation with civil initiatives like climate protection movements, public discourse and media presence.

The terms "success factors or criteria" are used in the sense that they positively influence the cooperation of the actors and the impact of transdisciplinary projects for climate change mitigation. On the other hand, a failure in meeting the criteria does not automatically imply a failure of the project itself.
Three basic factors of a successful implementation can be identified: Aspects of communication, measurability of activities, and continuity. In addition, a number of further and more detailed criteria can be added, which are derived from positive experiences of implemented projects. Some of them can be assigned to more than one aspect.
In order to define the effectiveness of a transdisciplinary project, some success criteria must be considered. One example is that the incorporation of impulses from participatory research into administrative practice is desirable and at best possible. This requires that all relevant perspectives and stocks of knowledge are integrated into the research process and used at the appropriate point. A visualisation of all processes, steps, and actors can be helpful here.
The basis of a transdisciplinary approach and the implementation of the results on the ground, is the exchange of knowledge and experience between the participating departments within a project. Here, experts from practice and outside the scientific community serve as specialists to evaluate the practicability of measures. The implementation of suitable measures and solutions must be directly considered in the research process and should meet the stakeholder's requirements to generate co-benefits (Gössling 2020; Creutzig et al. 2012; Harlan and Ruddell 2011; Knutti 2019). In other words, they should create positive effects in different fields of action and sectors and, thus, take several objectives into account (e.g. reduction of greenhouse gas emissions and positive effects on human health through the use of sustainable mobility solutions such as bicycles instead of cars). This is linked to a scientific knowledge process and a real-world problem-solving process (Pohl 2011; Leutz 2019; Hirsch Hadorn et al. 2008).
All actors benefit from establishing a network between scientific and non-scientific partners in an accompanying research process to ensure long-term cooperation (Schaufler and Staffa 2020; Fox-Kämper et al. 2020). Established networks promote successful collaboration and strengthen co-design processes. Feedback loops and the continuous discourse, during and outside of the project collaboration, form the basis for the establishment of an effective network (Schaufler and Staffa 2020; Fox-Kämper et al. 2020). Openness and transparency, identification of conflict dimensions, and conflict prevention are conducive strategies for successful research in the controversial area between different interests (Leutz 2019; Growe et al. 2018; Wagner et al. 2019; Kuckartz 2014; Bardal et al. 2020).

Another success factor is measurability, which was mentioned in two of the three expert interviews. The results show that it is important for civil society participants to observe the success or failure of their activities. Thus, in one interview, the creation of individual success criteria was recommended (Baum et al. 2020).
Furthermore, in all three interviews, continuity and, thus, the continuation of activities and support from the projects, was mentioned as a factor for a long-term impact of transdisciplinary projects and the transformation to a sustainable society. While summarising the results, it becomes clear that continuity must be considered from the beginning of the process (Schaufler and Staffa 2020; Parodi et al. 2020; Reallabor für nachhaltige Mobilitätskultur, Universität Stuttgart 2020; Neddermann and Rösener 2022). Additionally, all stakeholders have to be encouraged to act more independently (Fox-Kämper et al. 2020). On the other hand, in one interview continuity was also mentioned as a challenge, as it is demanding to transfer the exceptional conditions of an experiment into reality (Reallabor für nachhaltige Mobilitätskultur, Universität Stuttgart 2020). According to Parodi et al., different cycles of learning can be experienced through longer periods of time, continuously working towards permanence. This helps

to reflect and apply the research and practice results of real-world experiments (Parodi et al. 2018; Parodi et al. 2019; Bardal et al. 2020). Furthermore, Köglberger et al. emphasise, that a high degree of visibility through public outreach is important with regard to continuation (Köglberger et al. 2019).

Moreover, communication between the actors is a challenge. Communicating on the basis of different technical languages of the participating actors requires the definition of common terms and language levels. Also, the understanding of measures or regularities demands mutual clarification and is determined by institutional framework conditions (Lang et al. 2012; Fox-Kämper et al. 2020; Schaufler and Staffa 2020). Accordingly, the results of the empirical interview survey show, that the establishment of communication structures is an important factor for success. The necessity of professionally designed communication processes, transparent communication, and exchange at eye level are emphasised (Baum et al. 2020; Reallabor für nachhaltige Mobilitätskultur, Universität Stuttgart 2020; Fox-Kämper et al. 2020; Neddermann and Rösener 2022). Enough time must be scheduled for the preparatory explanation (Neddermann and Rösener 2022). Schneidewind underlines the importance of discussions at eye level in order to ensure, that the practice stakeholders do not feel like a researched object, but like they explicitly participate in the project (Schneidewind 2014). Through an open dialogue, an atmosphere of respect, understanding, and trust, should be created in order to reduce barriers between the actors (Reallabor für nachhaltige Mobilitätskultur, Universität Stuttgart 2020; Baum et al. 2020; Bardal et al. 2020). Furthermore, due to the encounter of different disciplines and stakeholders, expert knowledge and the disciplinary working language must be made comprehensible (Defila and Di Giulio 2018a; Defila and Di Giulio 2018b).

Transdisciplinary cooperation faces a variety of challenges: Diverse areas of competence and responsibility, time budgets, different prioritization, segmentation of the administrative level, dependencies on people and networks, neutrality versus positioning, pressure of expectations, resistance in the process flow, willingness to communicate and cooperate, background knowledge, attitudes and perspectives of the participants, or availability of funding (Schaufler and Staffa 2020; Parodi et al. 2019; Bergmann et al. 2021; Lang et al. 2012). Furthermore, the administrative level is challenged with a lack of trust and a kind of obligation to legitimize itself through external expert knowledge (Lang et al. 2012; Leutz 2019; Growe et al. 2018; Wagner et al. 2019).
The lack of a transdisciplinary infrastructure for exchange at the content and methodological level requires the creation of capacities, competencies, relationships, structures, and systems to ensure transfer and cooperation (capacity building) (Leutz 2019; Schneidewind 2018; Schneidewind and Singer-Brodowski 2013).

The results show similarities to the findings from seven real-world laboratories in Baden-Württemberg. A continuation of these projects in the science society is recommended in order to act as a catalyst for social change (Parodi et al. 2018; Parodi et al. 2019; Bergmann et al. 2021).

6 CONCLUSION

The aim of the study was to examine the contribution of transdisciplinary projects to climate change mitigation in cities with a focus on sustainable and climate friendly mobility. For this purpose, expert interviews were evaluated with qualitative content analysis and related to the current research literature. It was shown, that transdisciplinary projects, such as real-world laboratories, support climate change mitigation and the change towards a sustainable mobility

culture by contributing to the raising of awareness, setting of impulses, and showing how change can be initiated through the interaction of science and practice on a local scale.
Generally, it is not possible to achieve the formulation of legislation necessary for climate change mitigation, but structural changes can be triggered through transdisciplinary cooperation with politics and, thus, contribute to transformative processes. Another key finding is that the reach of transdisciplinary projects varies, depending on the event format of the real-life experiments in terms of age structure and awareness of climate change. It shows that the majority of the central stakeholders in transdisciplinary projects are already sensitised, motivated and committed to climate change before participating in an experiment or project. However, if participation is defined more broadly, real-life experiments and events reach larger groups of urban population of all ages.

In addition, challenges arise in transdisciplinary cooperation that make it more difficult for actors to work together and thus contribute to climate change mitigation. Central challenges are the voluntary commitment, the undefined and often extensive time frames, the short time limits of projects and experiments, communication barriers between the involved actors, as well as role conflicts. As with the challenges, the success factors also vary depending on the project. Transparent communication at eye level, the measurability of successes, and the continuity of activities and results emerge as central factors for successful cooperation (Bergmann et al. 2021; Bardal et al. 2020).

Conclusively, it was shown that despite existing challenges, transdisciplinary projects as transformative research formats have the potential to contribute to climate change mitigation by raising awareness in the population and by demonstrating and initiating a transformation towards a sustainable mobility culture. The knowledge of challenges and success factors can present an added value for practice, as well as for research to improve the work in transdisciplinary collaborations and to use the results for further studies.

The findings are limited in their representativeness, but show clear agreements with other studies and topic-related publications (Bergmann et al. 2021).

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