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Article

# The Scaling Potential of Experimental Knowledge in the Case of the Bauhaus.MobilityLab, Erfurt (Germany)

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**Abstract**

Real-world labs hold the potential to catalyse rapid urban transformations through real-world experimentation. Characterised by a rather radical, responsive, and location-specific nature, real-world labs face constraints in the scaling of experimental knowledge. To make a significant contribution to urban transformation, the produced knowledge must go beyond the level of a building, street, or small district where real-world experiments are conducted. Thus, a conflict arises between experimental boundaries and the stimulation of broader implications. The challenges of scaling experimental knowledge have been recognised as a problem, but remain largely unexplained. Based on this, the article will discuss the applicability of the "typology of amplification processes" by Lam et al. (2020) to explore and evaluate the potential of scaling experimental knowledge from real-world labs. The application of the typology is exemplified in the case of the Bauhaus.MobilityLab. The Bauhaus.MobilityLab takes a unique approach by testing and developing cross-sectoral mobility, energy, and logistics solutions with a distinct focus on scaling knowledge and innovation. For this case study, different qualitative research techniques are combined according to "within-method triangulation" and synthesised in a strengths, weaknesses, opportunities, and threats (SWOT) analysis. The analysis of the Bauhaus.MobilityLab proves that the "typology of amplification processes" is useful as a systematic approach to identifying and evaluating the potential of scaling experimental knowledge.

**Keywords**

amplification processes; Bauhaus.MobilityLab; experimental knowledge; real-world experiments; real-world labs; scaling; urban transformation

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## 1. Introduction

In a fast-changing and increasingly complex urban environment, where urbanisation and sustainability challenges overflow institutional, regional, and ontological boundaries (Kullman, 2013), real-world labs (RWLs) are increasingly gaining attention to initiate urban transformation processes (Kern & Haupt, 2021; Renn, 2018; Schneidewind et al., 2018; Singer-Brodowski et al., 2018).

The term "real-world lab" (*Reallabor*) is predominantly known in German-speaking countries and is defined as follows: RWLs provide the research infrastructure to conduct real-world experiments (RWEs) where co-creation of the research process (Defila & Di Giulio, 2018; Engels & Rogge, 2018; Kern & Haupt, 2021), co-production of knowledge (Borner & Kraft, 2018; Kern & Haupt, 2021; Renn, 2018; Schneidewind et al., 2018), and social learning (Kern & Haupt, 2021; Parodi et al., 2017; Schäpke et al., 2017; Singer-Brodowski et al., 2018) are of central importance. Thus, RWLs have conceptual similarities with the more widespread term "urban living labs" (Kern & Haupt, 2021). However, RWLs may concern a larger spatial unit of experimental activities (Kern & Haupt, 2021) such as city districts, entire cities, or even regions (Schäpke et al., 2017). Further, RWLs differ from urban living labs in their explicit focus on the temporal as well as spatial dimensioning of scaling experimental knowledge (Kern & Haupt, 2021). Nonetheless, the extent to which the experimental knowledge from an RWL (or an urban living lab) can move beyond experimental boundaries is largely unexplained (Evans & Karvonen, 2011; Kern & Haupt, 2021). The scaling of experimental knowledge from RWLs has been recognised as a problem but has barely become the object of systematic research (Kern & Haupt, 2021).

This article proceeds to outline current discussions on urban transformation through experimentation and what role experimental knowledge plays in urban planning. Thereupon, current research on scaling experimental knowledge, and in particular its constraints, are highlighted. Based on this, the study addresses the following research question: How does the "typology of amplification processes" by Lam et al. (2020) contribute to identifying, systematising, and evaluating the potential of scaling experimental knowledge of RWLs?

The typology, according to Lam et al. (2020), provides a promising framework to systematically understand and categorise different facets of scaling. The Bauhaus.MobilityLab (BML) in Erfurt, the capital of Thuringia, Germany, serves as an example of the application of the typology: In line with the notion of RWLs, the BML embraces a collaborative and interdisciplinary process that aims to shape new urban transformation. It tests and develops sustainable and intelligent mobility, logistics and energy solutions with a distinct focus on artificial intelligence (AI) approaches (BML, 2021). The BML innovation district Brühl serves as the nucleus of experimentation. However, experimental activities also take place outside Brühl and spread across the entire city of Erfurt. The experiments include incentivising mobility behaviour, pedestrian sensors, data management, last-mile logistics, and smart energy applications. Erfurt represents a prototypical European city, and thus promises scaling potential to other similar locations in Germany and Europe. The application to other areas, such as data-based services in the housing industry, the healthcare industry, in the area of eGovernment, smart city, or the financial sector is also intended (Bauhaus.MobilityLab Consortium, n.d.). Thus, the analysis of the BML allows drawing conclusions about the applicability of the typology, as well as the potential of scaling experimental knowledge of RWLs.

## 2. Urban Transformation Through Experimentation

According to Dorstewitz (2014, p. 434), "there is an increasing focus on processes of knowledge production [in urban planning], which gives a rise to the notion of 'urban laboratory.'" Therefore, it is necessary to understand what role RWLs, and in particular RWEs, play in knowledge production and urban planning.

As RWEs are restricted in their spatial and temporal reach, they strongly counter the traditional notion of comprehensive and long-term urban planning. "However, considering rather recent planning theory, linear-hierarchical stringent approaches to planning no longer seem to exist" (Räuchle, 2021a, p. 210). Instead, new forms of urban planning have emerged that are reflexive, responsive, and spatially delineated (Karvonen, 2018). Yet, there is no clear understanding of the ultimate role that RWEs can or should play in urban planning (Räuchle, 2021a; Voytenko et al., 2016). Also, according to Karvonen and van Heur (2014), there are conflicts and overlaps between RWEs and urban planning. On the one hand, "it is largely unclear whether far-reaching effects can be achieved at all through experimental approaches" (Räuchle, 2021a, p. 208). On the other hand, new forms of urban planning and RWEs are similarly interpreted as a collaborative, interdisciplinary process, concerning knowledge-intensive research activity and constituting place-specific trial-and-error interventions (Karvonen & van Heur, 2014). However, as Räuchle (2021a, p. 210) points out:

> There is one main difference: Urban planning aims to intervene in urban spaces and change them, whereas RWEs, in a first step, aim at revealing and explaining (causal) relationships between different dimensions in urban spaces. Only in a second step shall RWEs have a transformative effect in urban spaces.

Thus, the question arises of how experimental knowledge from RWE can be integrated into urban planning.

### 2.1. Experimental Knowledge in Urban Planning

In recent urban planning theory, knowledge has been recognised as socially constructed (Räuchle, 2021b), thus implying multiple forms of knowledge (Innes, 1995; Khakee et al., 2000). For instance, strict, deterministic, general knowledge has been gradually replaced by experimental knowledge which explores randomness, uniqueness, ambiguity, and unpredictability (Khakee et al., 2000), and thus matches the notion of "urban," where processes are notoriously inexact, improvised, and often uncontrollable (Dorstewitz, 2014). Despite high expectations, the far-reaching, sustainable urban transformation through experimental knowledge from RWLs failed to materialise. Respectively, there is a lack of theoretical and empirical evidence on the relationship between RWLs and urban transformation (Kern & Haupt, 2021; Räuchle, 2021b; von Wirth et al., 2019; Voytenko et al., 2016).

Räuchle (2021a), Beecroft et al. (2018), and ProClim (1997) distinguish three types of experimental knowledge: "knowledge about the urban context (system knowledge) and their own normative goals (target knowledge), [as well as] knowledge about how to achieve the set goals (transformation knowledge…)" (Räuchle, 2021a, p. 210). Thus, the knowledge produced in RWEs is of interest to urban planning (i.e., "system and target knowledge"; Räuchle, 2021a). "Transformation knowledge" may be used as an instrument in urban planning (Räuchle, 2021a). Schäpke et al. (2017, p. 210) add the concept of "actionable knowledge." This knowledge refers to an evidence-based orientation for practically implementable actions, and thus relates to "transformation knowledge." "Actionable knowledge" describes strategies that have successfully solved—or at least reduced—sustainability problems within the framework of an RWE (Forrest & Wiek, 2014; Frantzeskaki & Kabisch, 2016; Schäpke et al., 2017). It becomes evident that RWLs are caught between understanding ("system knowledge") and shaping urban transformation processes ("transformation knowledge"; Räuchle, 2021b; Schäpke et al., 2017). "With this postulated dual goal, a real-world lab…combines the implementation of concrete, real-world interventions…with their analysis and evaluation as well as the derivation of fundamental mechanisms of action with regard to the desired transformation" (Schäpke et al., 2017, p. 12).

Experimental knowledge production is a highly formalised process in RWLs (Bulkeley & Castán Broto, 2013; Kern & Haupt, 2021; Voytenko et al., 2016). The formalisation is particularly evident in its recursive nature (Evans & Karvonen, 2011; Kern & Haupt, 2021). Recursive knowledge aims to constantly develop, adapt, and thereby improve existing knowledge (Kern & Haupt, 2021; Tenberg, 2006). In practice, experimental knowledge in RWL is therefore characterised by repeated trial and error (Bulkeley et al., 2016; Kern & Haupt, 2021; Nesti, 2018; von Wirth et al., 2019; Wolfram & Frantzeskaki, 2016). At this point, it is important to note that the outcome of an RWE is "open," meaning that a successful RWE is not guaranteed (Räuchle, 2021a). Yet even failure may produce useful knowledge (Räuchle, 2021a).

### *2.2. Scaling Experimental Knowledge*

In the case of success, an RWE could be a concrete example of how to solve problems in other sufficiently similar contexts (Dorstewitz, 2014). According to Lam et al. (2020), a context is considered similar when basic social, ecological, political, or technical structures and dynamics do not differ significantly. Nonetheless, ever-changing contexts "make it more difficult or even impossible to observe cause-and-effect relationships between [context] dependent and independent variables" (Räuchle, 2021a, p. 209).

However, to make a significant contribution to urban transformation, the experimental knowledge of RWLs must go beyond the level of the building, street, or small district where RWEs are conducted (Dijk et al., 2018). Yet, there seems to be a rather fragmented understanding of the constraints on scaling experimental knowledge (Dijk et al., 2018), which is discussed in the following.

According to Kern and Haupt (2021), urban transformation requires the scaling of experiments while concerning the temporal and spatial dimensions of scaling. The temporal dimension of scaling faces the challenge that experiments are limited in time (Karvonen, 2018; Kern & Haupt, 2021). The question, therefore, arises as to how successful experiments can be sustained in the medium and long term (Kern & Haupt, 2021). In this respect, the perpetuation of the experiments is strongly dependent on funding and permanent institutionalisation (Kern & Haupt, 2021).

The spatial dimension of scaling refers to the spatial limitation of RWEs, which means that the results of successful experiments often cannot be directly scaled to another context (Dijk et al., 2018; Kern & Haupt, 2021). The problem lies in the decontextualisation of experimentation and the generalisation of knowledge (Ceschin, 2014; Leino & Åkerman, 2021; Schäpke et al., 2017; Van de Walle, 2017). In each new context, an experiment is repeated but with a new interpretation (Leino & Åkerman, 2021) and thus always dealing with improvisation as well (Freeman et al., 2011; Leino & Åkerman, 2021). Kern and Haupt (2021) suggest that institutionalisation plays an important role in the spatial dimension of scaling, too. Institutions influence experiments, and conversely, experiments can contribute to institutional change (Fuenfschilling et al., 2019; Kern & Haupt, 2021; McFadgen & Huitema, 2018). The medium and long term urban transformation therefore strongly depends on whether it is possible to embed RWLs and their experiments both temporally and spatially in existing institutional arrangements (Kern & Haupt, 2021).

However, the idea of scaling experimental knowledge clashes with siloed institutions, where there are clear and separate mandates for different officials and administrative departments (Leino & Åkerman, 2021). Siloed institutions are both embedded in an obdurate system and a deep-rooted habit (Leino & Åkerman, 2021). Thus, RWLs and RWEs intervene with the usual proceedings of institutions (Leino & Åkerman, 2021). In turn, it becomes rather elusive how to promote scaling experiments through institutionalisation.

Another constraint is that "many of the [real-world] experiments that emerge…are characteristically ambiguous, involve contradictory interests, and have evolving goal settings" (Leino & Åkerman, 2021, p. 11). This raises concerns over poor experimentation management resulting in information gaps, poor budgeting and documentation, as well as unclear roles of actors (Leino & Åkerman, 2021). Further, the degree to which an experiment can stimulate broader urban transformations much relies on the ability of actors to "jump scales," meaning to engage with actors on higher scale levels and shift the local power balance in favour of the experiments at the expense of vested interests (Dijk et al., 2018; Leino & Åkerman, 2021). However, the actors conducting experiments are often not the ones who set goals of scaling the knowledge from experimentation (Leino & Åkerman, 2021), which in turn highlights the lack of systematic consideration of scaling experimental knowledge.

It becomes evident that scaling experimental knowledge from RWLs requires the extraction of generic, process-related, and context-specific factors (Brown & Vergragt, 2008; Forrest & Wiek, 2015; Schäpke et al., 2017; Westley et al., 2014). Sharp and Raven (2021, p. 196) highlight that "there is a need to explore the enabling conditions and processes across multiple experiments and domains and across time-frames that go beyond those of single, 'projectified' experiments." The BML is developing a cross-sectoral laboratory infrastructure to conduct numerous experiments across different domains. In addition, it aims to be operated long term by developing the "lab as a service" concept (see Section 4). Thus, the BML allows exploring the scaling potential of experimental knowledge.

The "typology of amplification processes" by Lam et al. (2020) represents a relevant approach to identifying and systematising scaling processes. The scaling processes are divided into three categories and eight processes (see Section 3) and thus cover a large variety of processes. The typology caters specifically to sustainable initiatives, which foster new ways of thinking, doing, and organising social, technological, economic, socio-technical, and/or socio-ecological structures. Experiments in RWLs have similar traits and approaches to what Lam et al. (2020) describe as sustainable initiatives. Thus, the "typology of amplification processes" can be applied to the notion of RWLs.

## 3. Theoretical Framework

The amplification processes by Lam et al. (2020) are aggregated into the following three categories: amplifying within, amplifying out, and amplifying beyond. The categories include eight processes: stabilising, speeding up, growing, replicating, transferring, spreading, scaling, and scaling deep (see Figure 1). For this research, the following description of the processes already refers to RWLs and RWEs instead of sustainable initiatives, as originally formulated by Lam et al. (2020).

*Amplifying within* relates to processes that generally seek to increase the knowledge of RWLs by prolonging or speeding up the way an RWE produces knowledge (Lam et al., 2020). "Stabilising" means that RWLs are strengthened and embedded deeper in their context to make them more resilient to future challenges and to ensure that their impact lasts longer. It indicates that RWLs take action to capitalise on the existence of members, supporters, or users. In addition, it refers to processes that professionalise a streamlined work process as well as clear communication of purpose and mission. "Speeding up" involves the acceleration of mechanisms to produce knowledge from RWEs (Lam et al., 2020).

*Amplifying out* describes processes that seek to increase the experimental knowledge or the number of RWEs by involving more people and places (Lam et al., 2020). This category is divided into two subcategories according to the location of processes in similar or dissimilar contexts (see Figure 1). When basic social, ecological, political, or technical structures and dynamics do not differ significantly, a context is considered similar. Further, amplifying out differentiates processes that are dependent or independent, meaning whether they are dependent on the existing RWLs or not (see Figure 1). The first subcategory, including "growing" and "replicating,'' refers to processes that generate RWEs on existing RWLs. "Growing" concerns the expansion of experimental knowledge across a geographical location, organisation, or sector. To do so, the RWLs reach out with their programmes, products, solutions, or services, or by establishing affiliates that depend on the existing RWL. "Growing" and "replicating" describe comparable processes, only that "replicating" refers to processes in dissimilar contexts. The second subcategory concerns processes that create independent RWEs either by "transferring'' the RWE to another place with a similar context or by "spreading" the principles of an existing RWL to a dissimilar context. In contrast to the "growing" process, a similar but independent RWL emerges (Lam et al., 2020).

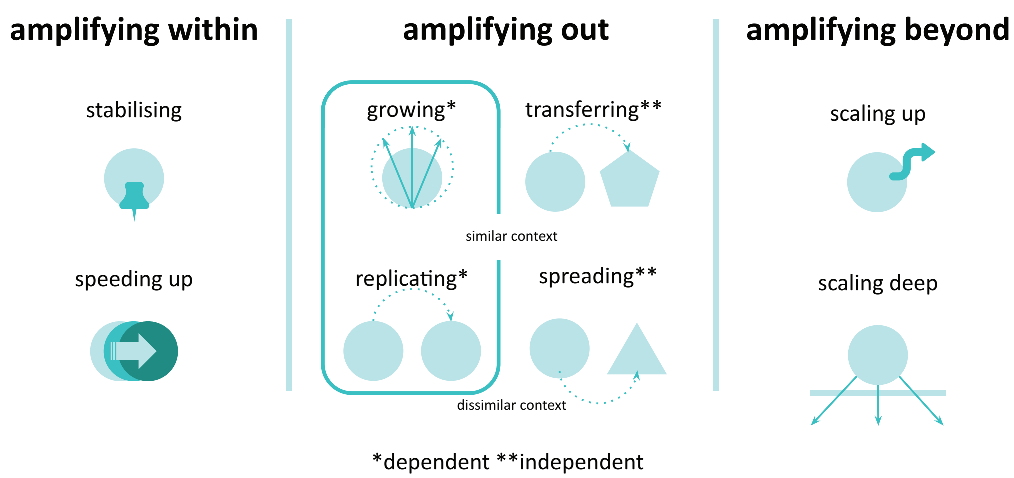


**Figure 1.** Typology of amplification processes based on Lam et al. (2020, p. 11).

*Amplifying beyond* involves processes that aim to increase their impact by reaching higher institutional levels ("scaling up") or by changing values ("scaling deep"; Lam et al., 2020). "Scaling up" includes codifying the knowledge of RWEs in laws, policies, or institutions through, for instance, lobbying, networking, or supporting alternative visions and discourses. "Scaling deep" involves processes that address the change of values, norms, and beliefs through fostering new mindsets, changing perceptions, and introducing new ways of relating and knowing as well as new value systems. Amplifying beyond processes differs from the other categories in that it suggests rethinking how RWLs produce knowledge (Lam et al., 2020).

The "typology of amplification processes" by Lam et al. (2020) represents a promising framework to identify and systematise the scaling potential of experimental knowledge. However, it is necessary to recognise that RWEs are complex, non-linear, context-specific, and place-based processes, which may even lead to negative, unanticipated, social, and environmental side effects (Evans & Karvonen, 2011; Lam et al., 2020; Schäpke et al., 2017; Smith et al., 2014). Thus, the scaling of experimental knowledge from RWLs cannot be characterised as positive or negative per se, nor do the described processes apply to all contexts and RWEs (Lam et al., 2020). In addition, the typology does not explicitly address contextual dependencies, which according to Dijk et al. (2018) display a constraint on scaling, or in this case, amplifying processes.

Nevertheless, the typology allows distinguishing different processes of amplification as well as individual interpretation of scaling experimental knowledge. Thus, it may even allow considering contextual dependencies.

## 4. Case Study: Applying the Amplification Processes to the Bauhaus.MobilityLab

In line with the vision of "innovation by experiment," the BML in Erfurt, Germany aims to provide a real-world environment for the development and testing of innovative solutions in the areas of mobility, energy, and logistics (Fraunhofer-Institut für Techno- und Wirtschaftsmathematik, 2022). With its 213,000 inhabitants, Erfurt, the capital of Thuringia, is an exemplary major European city (Bauhaus.MobilityLab Consortium, n.d.). According to the BML, the size of the city, measured by the number of inhabitants, the building structure, and the traffic integration suggest that Europe-wide scalability can be expected (Bauhaus.MobilityLab Consortium, n.d.).

The central component of the BML is its cloud platform, an open information and communication technology ecosystem ("BML-EcoSys") for RWLs (Institut für Innovation und Technik, 2021). On this AI-lab platform, collected and processed data is made available, interconnected, and evaluated. Therefore, AI algorithms are trained and optimised until they can analyse the data automatically. The district of Brühl in Erfurt serves as an RWL and nucleus for conducting experiments: Traffic lights are switched according to traffic volume, deliveries are delivered in a more customer-oriented manner, local energy generation reduces electricity costs, and intelligent tariff systems determine the charging price for e-cars. The idea is to test numerous data-based applications, which in turn will be evaluated on the project's AI-lab platform (Institut für Innovation und Technik, 2021).

The BML has a duration of three years (2020–2023) and is funded by the Federal Ministry for Economic Affairs and Energy to establish a "lab as a service." The "lab as a service" concept allows companies and initiatives to utilise the BML infrastructure, based on the AI-lab platform and the RWL, to test and develop new products and services. The interdisciplinary consortium consists of stakeholders from research institutions, companies, universities, and the city of Erfurt and is responsible for setting up the AI-lab platform and the BML innovation district Brühl. The network is complemented by lab users, lab customers, and infrastructure partners. The locally present and Europe-wide networked partner alliance promotes the BML in business, politics, and science (BML, 2021) and thus allows direct access to educational institutions and political lobbies. In addition, the BML is part of the national programme "Reallabore—Testräume für Innovation und Regulierung" (Real-World Labs—Test Sites for Innovation and Regulation) and is also taken into account for the development of legal foundations and the acquisition of knowledge by legislators (Bundesministerium für Wirtschaft und Klimaschutz, 2022). To build the lab infrastructure, the BML is organised in eight work packages (WPs): project management, AI-lab platform, infrastructure and data integration, AI technology, living lab, lab tools, lab innovations, and transfer and public relations. According to the respective function, different consortium partners work together in each WP (Bauhaus.MobilityLab Consortium, n.d.).

With its combination of an RWL and the AI-lab platform, the BML pursues a unique approach to producing and processing experimental knowledge that is "scalable and transferable to other municipalities" (Fraunhofer-Institut für Optronik, Systemtechnik und Bildauswertung, 2022). According to the BML, the selection of Erfurt as a "typical large European city" is also based on the idea of scaling the knowledge from the RWEs to other contexts (Institut für Innovation und Technik, 2021). As the "lab as a service" concept is still in an implementation phase at the time of the research (June 2021), the focus lies on how experimental knowledge is produced in the BML based on the organisation, structure, and characteristics of the RWL, and how this reflects on the scaling potential of experimental knowledge.

### *4.1. Methodology*

The research method "case study" entails the detailed and intensive analysis of a single case (Bryman, 2012).

In this case, the analysis evolves around the complexity and particular nature of the BML and aims to contextualise the research to create a better understanding of the study's specifics and its implications for the analysis.

The BML is one of many RWLs in the national laboratory programme "Reallabore" (see Section 4). Thus, the case study on the BML is considered to be an exemplifying case and implies useful results for other RWLs. In addition, it concerns a relevant research aim in the RWL field research and, therefore, allows engaging with the theoretical analysis provided by the literature review (see Section 2).

The study combines different qualitative research methods according to the "within-method triangulation" (Denzin, 1978, p. 301). Besides the desk-based examination of secondary data, such as project publications, presentation slides, images, illustrations, and websites, the case study involves primary data derived from qualitative methods, such as semi-structured interviews and participant observations.

Expert interviews play a central role in the research. A total of eight experts were interviewed. Based on their expertise and insight-knowledge, the BML WP leaders are considered to be valuable interview partners for this research. In addition, a representative of the associated BML partner aspern.mobil LAB, in Vienna, was interviewed. As a network of different stakeholders, the insights of the RWL partner provide relevant data regarding cooperation and knowledge transfer.

According to Jorgensen (1989, p. 2), participant observation "is exceptional for studying [amongst other things] processes…the organisation of people and events, continuities over time, and patterns." In consultation with the BML, the researcher participated in jour fixe meetings, the BML consortium meeting, and the living lab network meeting with the RWL MaaS L.A.B.S. The jour fixe meetings are weekly meetings of the individual WP, where work status updates and organisational matters are shared. The consortium meeting involves all BML partners and WPs and takes place every three to four months. The exchange during the consortium meeting serves to present the work status of the WPs and to clarify intersections, ideas, and coordination needs between the subprojects. The meeting between MaaS L.A.B.S. and BML was a first-time exchange of experiences and interests between the RWLs.

With the help of the different research methods, data on the goals and work processes of the BML, as well as the networking and communication between individual partners, the whole consortium and another RWL could be gathered. Following the "typology of amplification processes" by Lam et al. (2020), the collected data were clustered into the three categories of amplifying within, amplifying out, and amplifying beyond as well as their sub-processes. This allows a differentiated identification of processes for potentially scaling experimental knowledge of the BML. The results of the analysis are summarised using a strengths, weaknesses, opportunities, and threats (SWOT) analysis. This ensures a critical evaluation of the potentials and challenges for scaling experimental knowledge in the case of the BML.

### *4.2. Amplification Processes of the Bauhaus.MobilityLab*

To identify and evaluate amplification processes according to Lam et al. (2020), a distinct focus of the analysis lies on the preconditions for experimental knowledge production and measures for scaling experimental knowledge. For instance, in the following analysis, "stabilising" (amplifying within) processes focus on the way of working to secure a streamlined process and clear communication of purpose and mission, while "speeding up" (amplifying within) focuses on the BML's ways to increase the time and pace of organisational or implementation processes and thus increase experimental knowledge. Regarding the second category, amplifying out, the BML sets important prerequisites to involve more people and places that all show dependency on the BML AI-lab platform. For this reason, the independent processes of "transferring" and "spreading" were not considered in this analysis. Finally, the last category, "amplifying beyond," emphasises to what extent preconditions for a regime shift in higher institutional levels ("scaling up") and people's mindsets ("scaling deep") are created. In this respect, vision, enthusiasm, and intrinsic motivation play an important role. Overall, amplification processes were identified in all categories of the typology. Using the SWOT analysis, the identified processes for amplification were evaluated concerning existing potentials and obstacles (see Figure 2).

The committed and competent project partners are a central *strength* of the BML (WP 4, interview 2021-03-23; WP 6, interview 2021-03-22). This allows capitalising on existing resources ("stabilising" and "scaling up"). For example, the project partner Bauhaus-Universität Weimar utilised its network and brought the partners Bosch, Siemens, BPV Consult, and highQ on board of the research project (WP 6, interview 2021-03-22). The same applies to other project partners. In addition, the BML benefits from products and services, such as mobile applications (highQ) and sensors (Bosch) that companies bring into the project. This shows that the cooperation in the consortium is very trusting and allows project partners to benefit from joint resources (WP 6, interview 2021-03-22). Another strength is that the project partners from academia transfer knowledge produced by the BML into teaching (WP 2, interview 2021-03-22) and, thus, are directly involved in fostering new mindsets ("scaling deep"). Furthermore, as part of the national lab programme "Reallabore—Testräume für Innovation und Regulierung" (Bundesministerium für Wirtschaft und Klimaschutz, 2022), experimental knowledge is codified in laws and policies ("scaling up"), allowing to engage with higher institutional levels. A particularly unique feature of the BML is the cross-sectoral approach, which is conducive to expanding the experimental scope across different sectors ("growing"). The AI-lab platform supports this cross-sectoral approach by intelligently linking mobility, logistics, and energy data. It is available for other RWLs and lab customers who can use the AI-lab platform for data processing or the provision of AI tools (WP 6, interview 2021-03-22). Also, the AI-lab platform enables low-threshold transferability and thus the scaling of experimental knowledge. "For our AI methods, it doesn't matter whether these sensors are located in Erfurt or London" (WP 3, interview 2021-03-30). Thus, standardised data formats and the application of AI tools make it possible to extend the AI-lab platform and related services into similar ("growing") but also dissimilar contexts ("replicating").

However, the cross-sectoral and interdisciplinary cooperation between project partners can be a challenge or *weakness* for amplification processes ("stabilising"). WP 2 leader describes it as follows: "What I often find difficult is actually the wording. You notice that a lot of different disciplines come together, which sometimes use terms differently" (WP 2, interview 2021-03-22). A lack of common understanding of terminology is an obstacle to a common purpose and mission ("stabilising"). This also results in a lack of clear internal and external communication ("stabilising and growing").

In this regard, use cases represent an *opportunity* to make the BML more tangible ("stabilising" and "growing"). The identified lack of understanding of the complex project purpose and goals makes it necessary to not only improve communication with lab users and customers but also to involve them more in the product and service development process ("growing"; WP 5, interview 2021-03-25). Working with a marketing agency additionally helps to make the communication more effective in terms of publicity (WP 7, interview 2021-03-26). By reaching out to more people and getting them involved, important conditions are created to achieve a greater scaling potential, for example by promoting a change of values, norms, and beliefs ("stabilising" and "scaling deep"). Furthermore, the creation of a project-internal wiki contributes to clear communication of purpose and mission ("stabilising") but is also beneficial for the project organisation to find relevant content more quickly and easily ("speeding up"; WP 6, interview 2021-03-22; WP 5, interview 2021-03-25).

Finally, the informal character of networking and exchange with other living labs and associated partners, i.e., the aspern.mobil LAB, is considered a *threat*. Future cooperation may also suffer from the lack of insight into the complex, technical approach to the BML (aspern.mobil LAB, interview 2021-03-24).

### 4.3. Discussion

The literature review makes it clear that experimental knowledge production in RWLs is highly context-dependent and thus difficult to generalise. However, the analysis of the BML suggests that there are processes

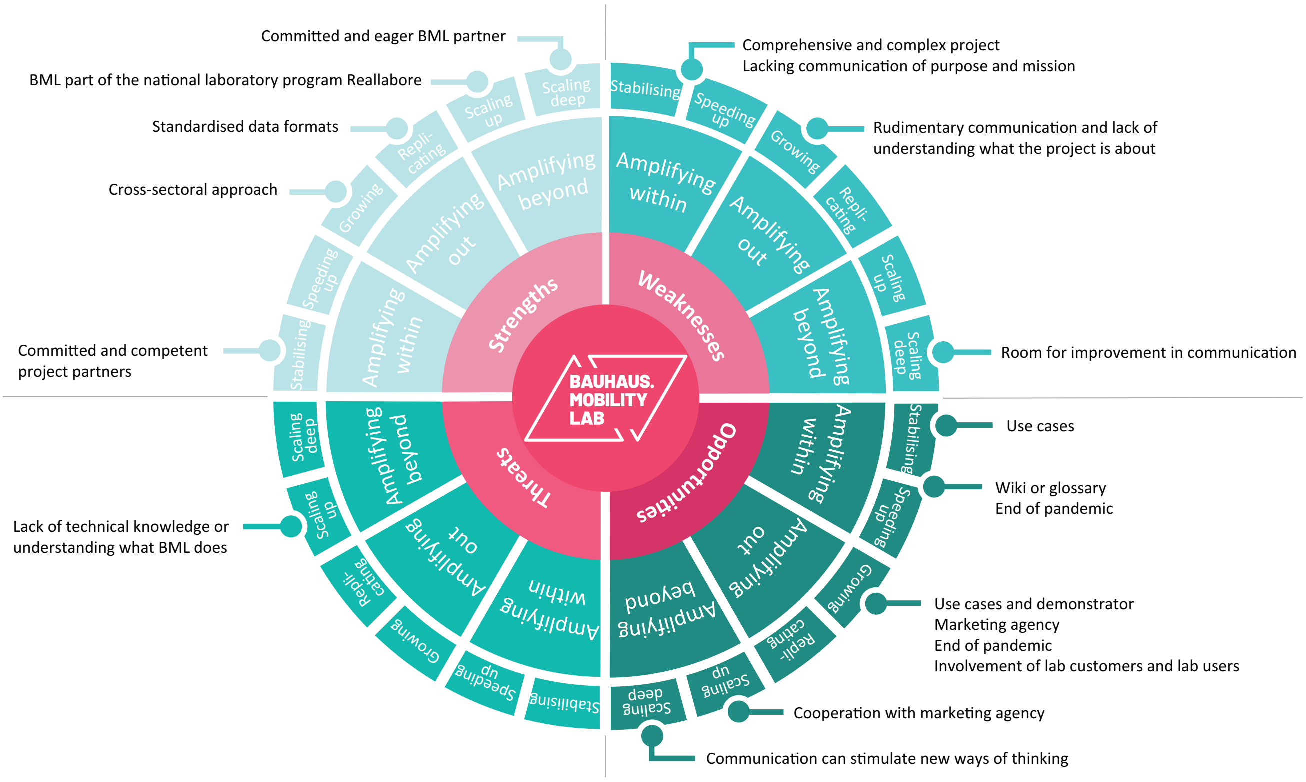


**Figure 2.** Repeatedly mentioned and common denominators of amplification processes in the BML according to Lam et al.'s (2020) "typology of amplification processes." Identified processes were assigned to SWOT.

that promise scaling potential of experimental knowledge. The concrete extent of the potential should be investigated in a follow-up study. The most relevant findings using the example of the BML are summarised below.

The literature suggests that spatial dimension plays a central role in the scaling potential of experimental knowledge (Kern & Haupt, 2021). The study of the BML shows that Erfurt, as a prototypical large European city, promises scaling potential. There are many cities in Germany and Europe that, like Erfurt, have a similar size, building structure, number of inhabitants, etc. (see Section 4). This suggests that experiments carried out in the BML can also be implemented in other similar contexts. A city such as Berlin and London, on the other hand, is very unique, which is why context-dependent parameters need to be considered more closely. Furthermore, the BML is to be sustained in the medium and long term based on the "lab as a service" concept. This means that companies and initiatives can use the laboratory infrastructure, consisting of the AI-lab platform and the RWL, to test and further develop their products and services. Therefore, an operating model is being developed to ensure the operation of the BML beyond the funding period of three years. The literature review also shows that urban transformation requires the institutionalisation of RWEs. This can be achieved by translating experimental knowledge into policies. Since the BML is still in the implementation phase, the concrete translation of experimental knowledge into policies cannot yet be investigated. However, the BML fulfils important prerequisites, as the analysis shows. For instance, the BML is part of the national RWL programme and thus has an exemplary role. In addition, the locally present and Europe-wide networked partner alliance promotes the BML in business, politics, and science (BML, 2021) and thus allows direct access to educational institutions and political lobbies.

### *4.4. Delimitations and Considerations*

As mentioned, the BML is still being implemented, which is why the study is only a snapshot and not a conclusive analysis. Therefore, the focus also lies on how experimental knowledge is produced in the BML based on the organisation, structure, and characteristics of the real-world lab, and how it reflects on the scaling potential of experimental knowledge. In the next step, a follow-up study is necessary to analyse what kind of experimental knowledge is produced to conclude the scaling potential. Although the implementation of the BML was at an early stage during this study (status June 2021), it makes sense to deal with scaling processes at an early stage, as possible obstacles or barriers can be uncovered and optimisations are made. This also corresponds to the iterative character and process of RWEs.

Furthermore, it is necessary to consider the circumstances of the current pandemic, which are affecting the BML structure, organisation, and communication and in turn the scaling potential of experimental knowledge.

## 5. Conclusion

Ultimately, it is unclear how RWLs contribute to urban transformation, as there is a lack of theoretical and empirical evidence on the relationship between RWLs and urban planning (Kern & Haupt, 2021; Räuchle, 2021b; von Wirth et al., 2019; Voytenko et al., 2016). Nonetheless, RWLs are argued to transform cities by promoting solution-oriented cooperation and actively contributing to a social change towards more sustainability (Alcántara et al., 2018). Kern and Haupt (2021) indicate that this urban transformation requires scaling of experimental knowledge, meaning that the knowledge must go beyond the level of a building, street, or small district where RWEs are conducted (Dijk et al., 2018). However, the literature review shows that it seems rather elusive how the scaling of experimental knowledge can be approached. Therefore, this study applied the "typology of amplification processes" by Lam et al. (2020) to the case of the BML as an approach to identify and systematise the scaling potential of experimental knowledge from RWLs. To accommodate the research question, i.e., how does the "typology of amplification processes" by Lam et al. (2020) contribute to identifying, systematising, and evaluating the potential of scaling experimental knowledge of RWLs, the amplification processes are summarised in a SWOT analysis, which allows evaluating the scaling potential.

Overall, most processes were identified in the *amplifying within* category ("stabilising" and "speeding up"). This is because the analysis took place during the setup and first implementation of the BML. A strong and active network shows that scaling up processes are in place ("growing"). In addition, the BML is part of the national real-world lab programme "Reallabore—Testräume für Innovation und Regulierung," which ensures the link to higher institutional levels ("scaling up"). "Scaling deep" processes take place in the sense that the BML is involved in teaching and thus is fostering new mindsets and changes of values. Furthermore, the strong commitment of all BML partners suggests that there is a desire for fundamental change and regime shift. The only processes that were not identified in line with the "typology of amplification processes" (Lam et al., 2020) are "transferring" and "spreading." The BML AI-lab platform acts as a common denominator to promote amplifying processes and, therefore, the BML does not aim for independent amplification processes. The evaluation of amplification processes shows that strengths or opportunities may also be considered weaknesses or threats, i.e., the cross-sectoral approach. However, opportunities provide possible approaches to overcome these weaknesses or threats.

The analysis proves that the "typology of amplification processes" is useful to identify and systematise the scaling potential of experimental knowledge of RWEs. Further, an early engagement with scaling potential makes sense when possible obstacles or barriers can be identified and improvements made. This is in line with the iterative character of RWLs to constantly rethink and, if necessary, refine the organisation and implementation of RWEs. However, a deeper examination of different methodological approaches to scaling experimental knowledge from RWLs is needed.

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**Conflict of Interests**

The authors declare no conflict of interests.

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