# Technology-Centric Real-World Labs: Challenges and Opportunities for a New Mode of Participatory Research From the Perspective of Computer Science

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## ABSTRACT

Real-World Labs (RWLs) hold the promise of directly involving citizens in shared shaping of research with the goal of societal transformation. However, particularly in the case of technology-centric RWLs, this is associated with unique challenges with respect to the way technology-based intervention is negotiated particularly with respect to accessibility and understanding of emerging technologies. In this position paper, we reflect upon these challenges on the basis of three RWLs, "Accessibility", "Artificial Intelligence and Robotics", and "Cooperative Autonomous Mobility". We close with guiding principles for technology-centric RWLs that we wish to discuss with the research community in an effort to ensure that the introduction of technological intervention does not threaten the democratic notion of the concept.

## KEYWORDS

Emerging Technologies, Participation, Real-World Lab Research

## 1 INTRODUCTION AND BACKGROUND

Real-World Labs (RWLs) are transdisciplinary efforts in which researchers engage in structured participatory research with citizens and other stakeholders [4]. Originally rooted in sustainability research, such labs seek to achieve transformation by means of direct engagement with society [3]. For example, RWLs have been employed to explore transformation to carbon neutrality in campus settings [6], in the context of aging societies [20], and in a range of other settings across Europe [23]. An important characteristic of RWLs is that research teams and citizens engage in collaborative shaping of research projects, jointly defining research questions, and openly discussing desirable research objectives and project outcomes. As such, RWLs share many of the characteristics of Participatory Design (PD) [21] – in particular, the aspiration to share power with participants [7] – and apply a similar set of methods (e.g., interviews and focus groups). However, they also carry an element of intervention [12], i.e., through employment of technology, they seek to produce change in citizen behaviour that is in alignment with overarching societal values such as sustainability [5]. Recently, there has been a push toward the application of RWLs in other domains, e.g., sport and exercise [33], and autonomous mobility [16], which has demonstrated the feasibility of the concept beyond sustainability research.

Particularly in the context of technology-centric RWLs, this opens up exciting research opportunities to create products that are aligned with citizens' needs and preferences while also taking into account values that should guide the design. **From the perspective of Computer Science and Engineering Sciences, we see potential in these RWLs as transdisciplinary research efforts that include the design, development and deployment of technological artifacts in shared spaces (rather than dedicated research labs), with the goal of iteratively designing and evaluating emerging technologies in conjunction with end-users, striving to devise artifacts that meet societal needs.** Here, Computer Science and Engineering Sciences could in particular benefit from medium- and long-term studies that also account for overarching societal values. However, from the perspective of researchers in technological domains, we argue that under consideration of these distinct characteristics, technology-centric RWLs are associated with unique challenges for our own domains of research, as well as for the Real-World Lab as a method of scientific enquiry. In the remainder of our paper, we discuss these challenges on the basis of three RWLs at Karlsruhe Institute of Technology (KIT), and


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reflect upon guiding principles for technology-centric Real-World Lab research.

## 2 CASE STUDIES: KIT REAL-WORLD LABS ON ACCESSIBILITY, AI AND ROBOTICS, AND COOPERATIVE AUTONOMOUS MOBILITY

The goal of the technology-centric RWLs at KIT is to facilitate technology development that takes place in conjunction with society, encompassing the human perspective and the desire to positively impact society, as well as the intention to advance technology and related research.

### 2.1 Case Study 1: Real-World Lab "Accessibility"

This RWL is concerned with the role that technology can play to improve inclusion of disabled people in society. The RWL takes a two-prong approach that examines the potential of assistive technology for disabled people on the one hand, and interventions that target non-disabled people on the other hand. One challenge here is that existing RWL research has not yet engaged with the privilege of participation [10], i.e., it is unclear how the method supports meaningful participation of disabled individuals, and there is a need to develop accessible formats of participation that also address inaccessibilities of emerging technologies (e.g., see [11, 13]) that often prevent hands-on exploration otherwise readily available to non-disabled individuals. Likewise, the lab is situated within the tension of clearly defined overarching societal values – access and inclusion – which are rooted in law (e.g., the UN Convention on the Rights of Persons With Disabilities [22]), but often poorly implemented. Here, a challenge for the lab is to mitigate the risk of technosolutionism [14], carefully telling apart instances in which technology can contribute to inclusion, and those where wider societal change must happen first [32], technology may not even be needed [2], or is not affordable [1]. Likewise, we are interested in trade-offs between new technologies (e.g., vision-based systems) and privacy concerns for users and bystanders, and want to engage in societal dialogue surrounding these.

### 2.2 Case Study 2: Real-World Lab "Artificial Intelligence and Robotics"

The RWL *Robotics AI* has been established with the goal of making AI tangible and debatable for society through humanoid robots. Real-world experiments in public space of the city of Karlsruhe —- from kindergarten, childcare centers, and schools to museums, city libraries, retirement homes, and hospitals -– are conducted with several humanoid robots to raise awareness of robotics AI technology by individuals and to gain new insights into the research and development of future AI robots. Through continuous interactions in real-world settings with different user groups, society and science come together on an equal footing to hand-in-hand co-develop embodied AI robot systems that align with users' needs and expectations. The goal is to reduce or close the knowledge gap between what is scientifically possible, and technologically feasible and what is expected by society through the co-development of these systems. Specifically, we address the following research questions, which also relate to the main challenges: (i) What is the attitude of different user groups towards robotics AI? How do people behave and feel when dealing with humanoid robots? What fears and expectations prevail, and in how far are they rooted in characteristics of the technology, or in people's ideas informed by media? (ii) How robust are current methods of AI-enabled humanoid robots for real-world applications? Which requirements for the robots result from practical use in long-term and weakly-controlled experiments with diverse users? and (iii) how can the suggestions and wishes of the user groups be incorporated and implemented in the design of new AI robot technologies?

### 2.3 Case Study 3: Real-World Lab "Cooperative Autonomous Mobility"

The RWL is dealing with the adoption of cooperative autonomous mobility as a part of future urban transportation systems with the overarching societal goal being the road safety. In comparison to existing testbeds, which mostly aim at the collection of the data enabling autonomous driving [26] or at the public demonstration of the specific use-cases [25], the RWL targets at understanding the user behavior changes when cooperative autonomous transport is in place. One challenge here is the low trust in the safety of autonomous systems [19], which might negatively impact the participation of end users. Another challenge closely related to the previous one comes from the level of technical maturity of urban autonomous mobility which limits its sustainability and increases the risks of insufficient user satisfaction [18]. For cooperative transport systems, the participation of a plethora of different stakeholders (e.g. automotive and telecommunication industries, respective authorities and regulators) is crucial. There is a non-stopping heated debate on the standardization of vehicular communications and related business incentives [30], which slows down the deployment of cooperative vehicles. The RWL provides such a participation platform. Reaching consensus among different players is especially important here since the cooperation between the vehicles is a technical enabler for making ethical decisions in autonomous driving [28].

## 3 GUIDING PRINCIPLES FOR TECHNOLOGY-CENTRIC RWLS

Reflecting upon these challenges and viewing them across three technology-centric RWLs, we believe that there is value for our community to define guiding principles for such research in an effort to ensure that they do in fact align with the aspiration of participation and democratization, outlining characteristics of RWLs that contradict traditional approaches in Computer Science research and Engineering Sciences.

- **Shared shaping of research and open-ended technology deployment.** Traditionally, our domains engage in technology-driven research where there is emphasis on development and deployment of a specific system that is only evaluated, but not shaped with end-users. In technology-centric RWLs, our domains need to take a step back and develop research approaches in which projects are defined and developed with end-users and stakeholders to align with the democratic notion of RWLs (e.g., see [4]. Likewise, technology-centric RWLs need to be open to the notion that

a given technology is not accepted in a given setting, or that non-technical solutions are preferred.

- **Understanding of technology.** When involving citizens in the envisioning of new systems, their understanding of underlying technologies and system capabilities becomes highly relevant to root the discourse in a realistic understanding of resulting artifacts, both in terms of individual expectations [17] and potential risks, challenges, and capabilities of technology, avoiding the reliance on *folk theories* [24]. Here, RWLs need to build on and expand existing research approaches that help create understanding of what future systems could look like, e.g., speculation [29] or careful construction of digital twinning studies [31] that could serve as intermediate step to foster understanding and create common ground for further conversation.
- **Inclusive and safe research sites and methods.** Computer and Engineering Sciences are faced with a twofold methodological research challenge in the context of Real-World Lab research: We systematically struggle with the inclusion of minoritized groups in research endeavours (e.g., see [15]), and many of the methods we employ are not accessible (e.g., see [9, 27]). Likewise, we traditionally engage in laboratory research particularly when new technology is deployed, allowing us to control the research setting and ensure safety of participants. In a RWL setting, we give up on that control, increasing the requirements for our systems with respect to their reliability. Particularly when working in sensitive settings, we anticipate that these two challenges will need to be addressed in conjunction.

## 4 OUTLOOK AND CONCLUSION

Real-World Labs offer the opportunity of engaging in shared research with society, thereby holding the promise of participation and citizen empowerment. However, particularly when considering technology-centric RWLs, barriers to true and inclusive participation remain, and our domains need to re-think established approaches to technology research. Here, the guiding principles discussed in our position paper provide a starting point, but are by no means comprehensive, and should therefore be subject to discussion within our research community. **In this context, we define the benchmark for success of technology-centric RWLs for our domain as twofold:** On the one hand, such labs must ultimately facilitate informed technology adoption (or rejection) within the population while aligning with overarching societal values in an effort to facilitate transformation, and avoiding a superficial operationalization of the concept of the RWL that has previously been considered a weakness of technology-centric RWLs [8]. On the other hand, technology-centric RWLs must provide Computer Science researchers and others with tangible tools to build such technology, and must serve as a space that helps our communities operationalize overarching values for technology integration in society in conjunction with relevant stakeholders and in a way that provides practical guidance that is mindful of technical dependencies and the dynamics that emerge when humans interact with technical systems.

## REFERENCES


[1] Jonathan Álvarez Ariza and Joshua M. Pearce. 2022. Low-Cost Assistive Technologies for Disabled People Using Open-Source Hardware and Software: A Systematic Literature Review. *IEEE Access* 10 (2022), 124894–124927. https://doi.org/10.1109/ACCESS.2022.3221449

[2] Eric P. S. Baumer, Jenna Burrell, Morgan G. Ames, Jed R. Brubaker, and Paul Dourish. 2015. On the Importance and Implications of Studying Technology Non-Use. *Interactions* 22, 2 (feb 2015), 52–56. https://doi.org/10.1145/2723667

[3] Richard Beecroft and Oliver Parodi. 2016. Reallabore als Orte der Nachhaltigkeitsforschung und Transformation: Einführung in den Schwerpunkt. *TATuP - Zeitschrift für Technikfolgenabschätzung in Theorie und Praxis* 25, 3 (Nov. 2016), 4–8. https://doi.org/10.14512/tatup.25.3.4

[4] Richard Beecroft, Helena Trenks, Regina Rhodius, Christina Benighaus, and Oliver Parodi. 2018. *Reallabore als Rahmen transformativer und transdisziplinärer Forschung: Ziele und Designprinzipien.* Springer Fachmedien Wiesbaden, Wiesbaden, 75–100. https://doi.org/10.1007/978-3-658-21530-9_4

[5] Schäpke N. Marg O. et al. Bergmann, M. 2021. Transdisciplinary sustainability research in real-world labs: success factors and methods for change. *Sustain. Sci.* 16 (2021), 541–564. https://doi.org/10.1007/s11625-020-00886-8

[6] Lisa Botero, Michael Bossert, Ursula Eicker, Jan Cremers, Nansi Palla, and Christiane Schoch. 2017. *A Real-World Lab Approach to the Carbon Neutral Campus Transition: A Case Study.* Springer International Publishing, Cham, 73–88. https://doi.org/10.1007/978-3-319-47895-1_5

[7] Tone Bratteteig and Ina Wagner. 2012. Disentangling Power and Decision-Making in Participatory Design. In *Proceedings of the 12th Participatory Design Conference: Research Papers - Volume 1* (Roskilde, Denmark) *(PDC '12)*. Association for Computing Machinery, New York, NY, USA, 41–50. https://doi.org/10.1145/2347635.2347642

[8] Stefan Böschen, Julia Backhaus, Ana de la Varga, Stefan John, and Gabriele Gramelsberger. 2021. *Reallabore: Simulierte Experimente – Simulierte Demokratie?* transcript Verlag, Bielefeld, 275–302. https://doi.org/doi:10.1515/9783839454534-012

[9] Betty-Jean M Dee-Price, Lorna Hallahan, Diane Nelson Bryen, and Joanne M Watson. 2021. Every voice counts: exploring communication accessible research methods. *Disability & Society* 36, 2 (2021), 240–264. https://doi.org/10.1080/09687599.2020.1715924 arXiv:https://doi.org/10.1080/09687599.2020.1715924

[10] Gordon C. C. Douglas. 2019. *Privilege and Participation: On the DemocraticDemocracy Implications and Social Contradictions of Bottom-Up Urbanisms.* Springer International Publishing, Cham, 305–321. https://doi.org/10.1007/978-3-319-90131-2_19

[11] Kathrin Gerling and Katta Spiel. 2021. A Critical Examination of Virtual Reality Technology in the Context of the Minority Body. In *Proceedings of the 2021 CHI Conference on Human Factors in Computing Systems* (Yokohama, Japan) *(CHI '21)*. Association for Computing Machinery, New York, NY, USA, Article 599, 14 pages. https://doi.org/10.1145/3411764.3445196

[12] Teresa Kampfmann, Philip Bernert, and Daniel J Lang. 2022. Toward a modular evaluation approach of real-world laboratories: Findings from a literature review. *Research Evaluation* (10 2022). https://doi.org/10.1093/reseval/rvac029 arXiv:https://academic.oup.com/rev/advance-article-pdf/doi/10.1093/reseval/rvac029/46632332/rvac029.pdf rvac029.

[13] Shaun K. Kane, Anhong Guo, and Meredith Ringel Morris. 2020. Sense and Accessibility: Understanding People with Physical Disabilities' Experiences with Sensing Systems. In *Proceedings of the 22nd International ACM SIGACCESS Conference on Computers and Accessibility* (Virtual Event, Greece) *(ASSETS '20)*. Association for Computing Machinery, New York, NY, USA, Article 42, 14 pages. https://doi.org/10.1145/3373625.3416990

[14] Silvia Lindtner, Shaowen Bardzell, and Jeffrey Bardzell. 2016. Reconstituting the Utopian Vision of Making: HCI After Technosolutionism. In *Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems* (San Jose, California, USA) *(CHI '16)*. Association for Computing Machinery, New York, NY, USA, 1390–1402. https://doi.org/10.1145/2858036.2858506

[15] Sebastian Linxen, Christian Sturm, Florian Brühlmann, Vincent Cassau, Klaus Opwis, and Katharina Reinecke. 2021. How WEIRD is CHI?. In *Proceedings of the 2021 CHI Conference on Human Factors in Computing Systems* (Yokohama, Japan) *(CHI '21)*. Association for Computing Machinery, New York, NY, USA, Article 143, 14 pages. https://doi.org/10.1145/3411764.3445488

[16] Nicola Marsden, Tobias Bernecker, Raoul Zöllner, Nico Sußmann, and Sebastian Kapser. 2018. BUGA:Log – A Real-World Laboratory Approach to Designing an Automated Transport System for Goods in Urban Areas. In *2018 IEEE International Conference on Engineering, Technology and Innovation (ICE/ITMC)*. 1–9. https://doi.org/10.1109/ICE.2018.8436361

[17] Roisin McNaney, John Vines, Daniel Roggen, Madeline Balaam, Pengfei Zhang, Ivan Poliakov, and Patrick Olivier. 2014. Exploring the Acceptability of Google Glass as an Everyday Assistive Device for People with Parkinson's. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (Toronto, Ontario, Canada) *(CHI '14)*. Association for Computing Machinery, New York, NY, USA, 2551–2554. https://doi.org/10.1145/2556288.2557092

[18] Kostas Mouratidis and Victoria Cobeña Serrano. 2021. Autonomous buses: Intentions to use, passenger experiences, and suggestions for improvement. *Transportation Research Part F: Traffic Psychology and Behaviour* 76 (2021), 321–335. https://doi.org/10.1016/j.trf.2020.12.007

[19] Mohammad Reza Mousavi, Ana Cavalcanti, Michael Fisher, Louise Dennis, Rob Hierons, Bilal Kaddouh, Effie Lai-Chong Law, Rob Richardson, Jan Oliver Ringer, Ivan Tyukin, and Jim Woodcock. 2023. Trustworthy Autonomous Systems Through Verifiability. *Computer* 56, 2 (2023), 40–47. https://doi.org/10.1109/MC.2022.3192206

[20] Claudia Müller, Dominik Hornung, Theodor Hamm, and Volker Wulf. 2015. Practice-Based Design of a Neighborhood Portal: Focusing on Elderly Tenants in a City Quarter Living Lab. In *Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems* (Seoul, Republic of Korea) *(CHI '15)*. Association for Computing Machinery, New York, NY, USA, 2295–2304. https://doi.org/10.1145/2702123.2702449

[21] Michael J. Muller and Sarah Kuhn. 1993. Participatory Design. *Commun. ACM* 36, 6 (jun 1993), 24–28. https://doi.org/10.1145/153571.255960

[22] United Nations. 2023. *Convention on the Rights of Persons with Disabilities*. Retrieved June 6, 2023 from https://social.desa.un.org/issues/disability/crpd/convention-on-the-rights-of-persons-with-disabilities-crpd

[23] European Network of Living Labs. 2023. *Discover Living Labs.* Retrieved June 6, 2023 from https://enoll.org/network/living-labs/

[24] Erika Shehan Poole, Christopher A. Le Dantec, James R. Eagan, and W. Keith Edwards. 2008. Reflecting on the Invisible: Understanding End-User Perceptions of Ubiquitous Computing. In *Proceedings of the 10th International Conference on Ubiquitous Computing* (Seoul, Korea) *(UbiComp '08)*. Association for Computing Machinery, New York, NY, USA, 192–201. https://doi.org/10.1145/1409635.1409662

[25] Pedro Rito, Ana Almeida, Andreia Figueiredo, Christian Gomes, Pedro Teixeira, Rodrigo Rosmaninho, Rui Lopes, Duarte Dias, Gonçalo Vítor, Gonçalo Perna, Miguel Silva, Carlos Senna, Duarte Raposo, Miguel Luís, Susana Sargento, Arnaldo Oliveira, and Nuno Borges de Carvalho. 2023. Aveiro Tech City Living Lab: A Communication, Sensing and Computing Platform for City Environments. *IEEE Internet of Things Journal* (2023), 1–1. https://doi.org/10.1109/JIOT.2023.3262627

[26] Kevin Rösch, Florian Heidecker, Julian Truetsch, Kamil Kowol, Clemens Schicktanz, Maarten Bieshaare, Bernhard Sick, and Christoph Stiller. 2022. Space, Time, and Interaction: A Taxonomy of Corner Cases in Trajectory Datasets for Automated Driving. In *2022 IEEE Symposium Series on Computational Intelligence (SSCI)*. 86–93. https://doi.org/10.1109/SSCI51031.2022.10022241

[27] J. Seo. 2019. Is the Maker Movement Inclusive of ANYONE?: Three Accessibility Considerations to Invite Blind Makers to the Making World. *TechTrends* 63 (2019), 514–520. https://doi.org/10.1007/s11528-019-00377-3

[28] Galina Sidorenko, Johan Thunberg, and Alexey Vinel. 2023. Ethical V2X: Cooperative Driving as the Only Ethical Path to Multi-Vehicle Safety. *IEEE Transactions on Intelligent Vehicles* (2023).

[29] Adalberto L. Simeone, Robbe Cools, Stan Depuydt, João Maria Gomes, Piet Goris, Joseph Grocott, Augusto Esteves, and Kathrin Gerling. 2022. Immersive Speculative Enactments: Bringing Future Scenarios and Technology to Life Using Virtual Reality. In *Proceedings of the 2022 CHI Conference on Human Factors in Computing Systems* (New Orleans, LA, USA) *(CHI '22)*. Association for Computing Machinery, New York, NY, USA, Article 17, 20 pages. https://doi.org/10.1145/3491102.3517492

[30] Elisabeth Uhlemann. 2022. Legislation Supports Autonomous Vehicles But Not Connected Ones [Connected and Automated Vehicles]. *IEEE Vehicular Technology Magazine* 17, 2 (2022), 112–115. https://doi.org/10.1109/MVT.2022.3159987

[31] Fanny Vainionpää, Marianne Kinnula, Atte Kinnula, Kari Kuutti, and Simo Hosio. 2022. HCI and Digital Twins – A Critical Look: A Literature Review. In *Proceedings of the 25th International Academic Mindtrek Conference* (Tampere, Finland) *(Academic Mindtrek '22)*. Association for Computing Machinery, New York, NY, USA, 75–88. https://doi.org/10.1145/3569219.3569376

[32] Bert Vandenberghe, Kathrin Gerling, Luc Geurts, and Vero Vanden Abeele. 2022. Maker Technology and the Promise of Empowerment in a Flemish School for Disabled Children. In *Proceedings of the 2022 CHI Conference on Human Factors in Computing Systems* (New Orleans, LA, USA) *(CHI '22)*. Association for Computing Machinery, New York, NY, USA, Article 546, 18 pages. https://doi.org/10.1145/3491102.3501853

[33] Beecroft R. Trenks H. Seebacher A. Wäsche, H. and O. Parodi. 2021. Transdisciplinary sport and physical activity development in urban real-world labs. *International Journal of Sports Marketing and Sponsorship* 22, 4 (2021), 816–833. https://doi.org/10.1108/IJSMS-05-2020-0081