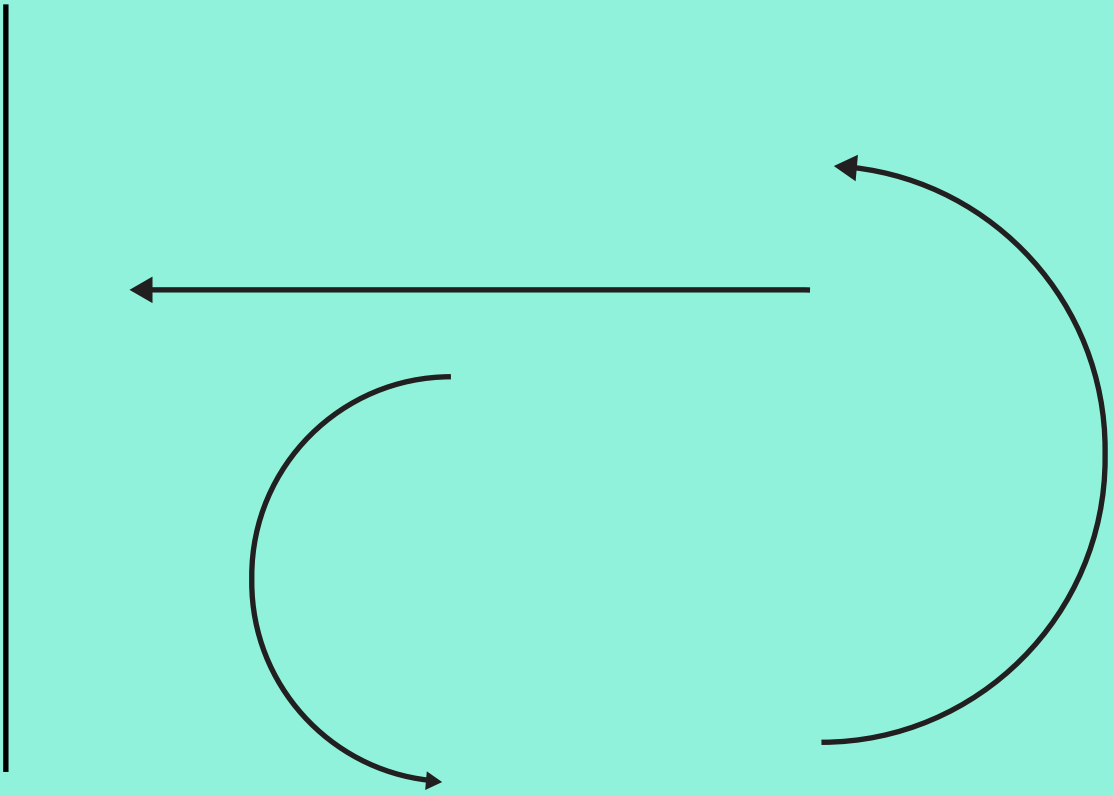
open
source
lab

THE OPEN SOURCE PARADIGM IN THE DIGITAL TRANSFORMATION — ENABLING A SUSTAINABLE FUTURE IN MOBILITY



White Paper — March 2019

Executive Summary

Mobility as a fundamental premise of human society accounts for a **significant share of CO_2 emissions globally.** With the digital transformation under way, mobility is becoming **digitally connected and data-driven.** If managed well, these disruptions present opportunities for a sustainable future of mobility. Potential is in the **Open Source paradigm for mobility solutions** being steered by sharing information, data, and resources as well as providing full transparency, involving diverse stakeholders, and co-developing sustainable mobility solutions. Such an approach to networked mobility comprises open access to anonymized mobility related data for third party actors beyond traditional silos, enrichment of this data to demand-based, high quality services benefiting the public at large, and scaling up sustainable solutions in fast forward with fewer legal barriers and lower cost for encouraging reuse.

Open Source as the default in mobility with incorporated **data sharing schemes** not only inspires innovation but may **also improve public services** through third party collaboration as well as learning between government agencies, businesses, and the public. Data sharing between the public (in the form of Open Data) and private sector will play a critical role in facilitating such an **Open Source Innovation Ecosystem for mobility.**

Digitalization can help optimize the transport sector, but **rebound effects** limit the sustainability impacts with gains in efficiency outweighed by increases in consumption and thereby the resource and energy demand. Concerning data use on a social scale, a **fair digital value chain** largely depends on the regulatory framework conditions for data sovereignty, data rights, and control, for example. However, emerging governance models, such as **Data Commons and Collectives**, emerging technologies, such as **blockchain powered Smart Contracts**, and the Open Source paradigm are highlighting potential sustainable digital developments. Meanwhile, many endeavors have already come to terms with the "super powers of Open Source" generating **benefits** on several levels. Open Source assets and data sharing can play crucial roles in reducing the barriers for entrepreneurs, in concentrating research progress on common platforms **producing standards**, but also in improving the links and connections between all of the stakeholders — public and private.

Barriers for Open Source Innovation in mobility are found within the political, organizational, legal, technical, and financial domain as well as low awareness on the availability of mobility related data and the specific needs of users of data and, respectively, Open Source contributors (e.g. developers or communities) leaves room for improvement.

Open Source can be a catalyst for sustainable transformation, aiming at **governing digitization to provide means of innovation** to everyone. Elaborating on our initial research and expert discussions we formulate **Open Source Mobility theses** intending to deepen the discourse in the field:

→ A Level Playing Field of Openness for Driving Sustainability;
→ Data Literacy for a Data Sharing Culture;
→ Embedded Intelligent Mobility in Economy and Society;
→ Public Value in Public Transport.

In order to engage increasingly more stakeholders in the debate on and the design of our future, we propose a range of **policy recommendations** addressing the **Open Source Innovation Ecosystem** for mobility and beyond:

→ Integrating Open Source production in **publicly funded projects** and establishing **public platforms** for running pilots and experiments, allowing small, completely new ideas to be scaled up when successful.
→ Ensuring data security and transparency in business models by setting legally binding **standards on an ethical and technical level** to ensure trustworthiness, and **incentivizing data sharing** through real benefits.
→ Merging public and individual transport thereby raising the quality of public transport for users and allowing for **publicly regulated measures** (e.g. citizen-led initiatives).
→ Fostering the development of personal mobility accounts with clear and easy-to-use interfaces to **reduce the data flood** for users, raise the **quality of transport data**, enable data sharing and to become conscious about the relations between mobility behavior and emissions.

To deepen the understanding of the Open Source Innovation Ecosystem, **further research** conducted on the best practices of Open Source policies in general, their deficiencies in mobility, contemporary cause and context of mobility behavior, and the impact of digital solutions in mobility in terms of **sustainability** needs to be carried out. Furthermore, the co-creation of **business models and public interest** in Open Source mobility solutions, the development and testing of tools enabling public access and contribution (e.g. data commons and data collectives), as well as ways to raise **data literacy** are crucial endeavors on the path to an Innovation Ecosystem within the Open Source Paradigm.

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Acknowledgements

This White Paper has been a collaborative effort as it elaborates on the roundtable discussion "Open Source Shared Mobility" that took place at the Open Source Lab in November 2018 with a group of mobility and digitalization experts. For their comments and suggestions, in particular in the development of this written piece, we are thankful to Max Kortlander of Waag, Netherlands; Gabriel Plassat of FabMob, France; Eleftherios Avramidis of DFKI, Germany, and Beate Kubitz of Travelspirit, UK.

Introduction

Mobility is a fundamental premise of human society that enables social participation and economic and cultural exchange. The current debates on how it is shaped and governed relate to its great importance in creating public value at large as well as its economic and ecological costs and benefits. With transport accounting for approximately 23% of CO_2 emissions from fossil fuels globally and up to 33% by 2050 [1] under a "business as usual" scenario, it is also a major challenge in terms of sustainability. This paper presents the main convictions of the Open Source Lab and elaborates on one main claim: The digital transformation, under way globally, can be an enabler for sustainable mobility solutions if the default paradigm for this transformation is Open Source. As technological change is clearly outpacing the capacity of systems and structures of governance [2] to respond, now is a critical time for local governments, policymakers, industry, academia and civil society to set the agenda for the challenges ahead. Due to its pace, we need to reimagine the mode of global change from closed-in, proprietary developments to Open Source, peer production and open innovation. Because profit-driven, exclusive generation and distribution of mobility solutions not only often fails to meet real demands but restricts the potential benefits and progress in terms of sustainability and accessibility. With this paper we want to set a cornerstone for building up a community of like-minded Open Source Pioneers as well as to address policymakers in gaining an understanding of the great potentials of the Open Source paradigm in mobility, steered by: sharing information, data and resources; providing full transparency; involving diverse stakeholders; creating an open innovation ecosystem and co-developing sustainable mobility solutions. This paradigm, laid out in the present paper, is leading the Open Source Lab, an international initiative started by the Sustainability Council of the Volkswagen Group and run by the German Research Center for Artificial Intelligence (DFKI) in Berlin, Germany, to include stakeholder

1 **World Bank (2017).** *Results Briefs*, **Mobility, December 2017. Available: https://www.worldbank.org/en/results/2017/12/01/ mobility**

2 **Docherty, I., Marsden, G., Anabel, J. "The governance of smart mobility",** *Transportation Research Part A: Policy and Practice 115*, **pp 114-125, 2018. https://doi.org/10.1016/j.tra.2017.09.012**

groups and outside actors in the discussion on Open Source futures in the mobility field beyond current industries. These Open Source futures are often intertwined with the facilitation of Open Data as the universal term for allowing access to, use, reuse, and redistribution of data, thereby putting it into the public domain. When it comes to evaluating the impact of Open Source projects in mobility, the most well documented examples are the combinations of open datasets issued by public authorities and Open Source software efforts making use of this data. Both concepts — Open Source and Open Data — as well as further movements (e.g. Open Patents) are defined by the open definition [3] highlighting similarities and grounding them all in 'openness'. Nevertheless, there are differences in the infrastructure of these two strands, with Open Source relying largely on a community of contributors, whereas Open Data is predominately published by a single organization. In this paper, we discuss an Open Source Innovation Ecosystem that relies on sharing mobility related data, appreciating Open Data initiatives in transport and using some related case studies as examples, while being aware that the debate is much deeper than what we are covering here.

Mobility in the Network Age

By 2020, a whole generation will have grown up in a primarily digital world. The network age or digital transformation is at an inflection point: While virtually all everyday objects are set to enter a networked interconnection to exchange information in real-time, the human understanding of this rapid and constant change in technology is challenged. The conversion of analogue information into zeroes and ones in order for computers to store, process, and transmit such information is currently impacting all areas of life, including the mobility domain. On the one hand, this gives rise to hoping the advanced processing of real-time data will help a comprehensive understanding of user behavior and thus give the possibility to experience mobility as an ecosystem of multimodal movement and access. On the other hand, the bigger picture is still a dilemma as the need for mobility will continue to increase in the next few years. This is because of factors such as population growth, the coupling of mobility and economic growth, the need for self-fulfillment in industrialized countries, and for food and safety from a global perspective [4]. The 'smart transition' mostly led by innovations originating in the technology sector, as a way out of the mobility dilemma, follows Moore's law: Everything digital gets faster, cheaper, and smaller at an exponential rate [5] and the rate of technology adoption in Western societies is still accelerating [6]. Although technology means nothing, in and of itself, when it is animated by human ideas, the real impact that it will eventually have on society is often what we least expect [7].

3 http://opendefinition.org/od/2.1/en/

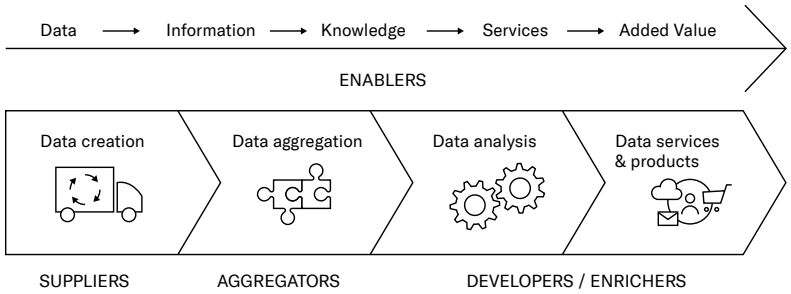
4 Sigrist, S., Achermann, S., Pabst, S., W.I.R.E. (Eds), (2016). *ABSTRACT* No. 15 – Transforming Transport, p 134, Zürich: Neue Züricher Zeitung Publishing

5 Mack, C. (2015). The Multiple Lives of Moore's Law, *IEEE Spectrum* 52(4), p 31-31. https://doi.org/10.1109/MSPEC.2015.7065415

6 For the telephone in the US it took 70 years to reach the 50% quota of households, for internet access it was only 10 years see: https://www.flickr.com/photos/adam_thierer/2199183611/

7 Ito, J. & Howe, J. (2016). *Whiplash: how to survive our faster future*. New York, NY: Grand Central Publishing

Image 1 **Data Value Chain Archetypes**



A visualization of the data re-use process and the digital value chain.

Source: **European Data Portal**

A Data-driven Future of Mobility

The other key ingredient for future mobility is data and its availability. Data on transportation carries the potential for a significant impact. Jeni Tennison, CEO at the Open Data Institute, points out how: "In fact, data is becoming as important as other types of infrastructure, such as roads and electricity, which means building strong data infrastructure is vital to economic growth and wellbeing. The rewards can be enormous. For example, it has been estimated that by using Open Data effectively, 629 million hours of unnecessary waiting time could be saved on the EU's roads and energy consumption could be reduced by 16 per cent" [8].

Data sharing between the public and private sector will play a critical role in helping transit agencies leverage future disruptions in mobility induced by shared mobility services and be of even greater service to their community by adapting to user needs, for example.

Making data freely accessible and legally useable (determined by a proper public domain license [3]) via online platforms and portals under the term Open Data has been gaining more awareness in the last couple of years. Similar to software, what makes data 'Open' is primarily defined by the license used. It must be pointed out that only a few data licenses can be considered truly Open Data licenses [9]. While the sharing of (research) data developed early within the scientific community, public authorities and governments are now at the center of attention. Globally, several governments have made concrete commitments to champion Open Data, either by adopting the Open Data Charter, or, as members of the G20, by signing up to the G20 Anti-Corruption Open Data Principles. However, progress is still faltering according to the Open Data Barometer [10]: fewer than 1 in 5 datasets are open and the vast majority of datasets remain closed to the public. Nevertheless, within these governments, transport data, with a quota of 30% being open, is at the top of the list of available Government Data. Overall, websites collecting data on transit feeds, for example, have identified over 870 transit feeds in over 500 locations containing 2,275 transit operators worldwide.

8 **"TfL's free open data boosts London's economy", Transport for London,** *press release*, **October 13, 2017. Available: https://tfl.gov.uk/info-for/media/press-releases/2017/october/tfl-s-free-open-data-boosts-london-s-economy**

9 **Hengl T., Wheeler I., MacMillan RA. (2018). A brief introduction to Open Data, Open Source Software and Collective Intelligence for environmental data creators and users.** *PeerJ Preprints* **6:e27127v2. https://doi.org/10.7287/peerj.preprints.27127v2**

10 **World Wide Web Foundation (2018). Open Data Barometer - Leaders Edition. Washington DC: World Wide Web Foundation. Available: https://opendatabarometer.org/doc/leadersEdition/ODB-leadersEdition-Report.pdf**

Toward the Open Internet of Mobility

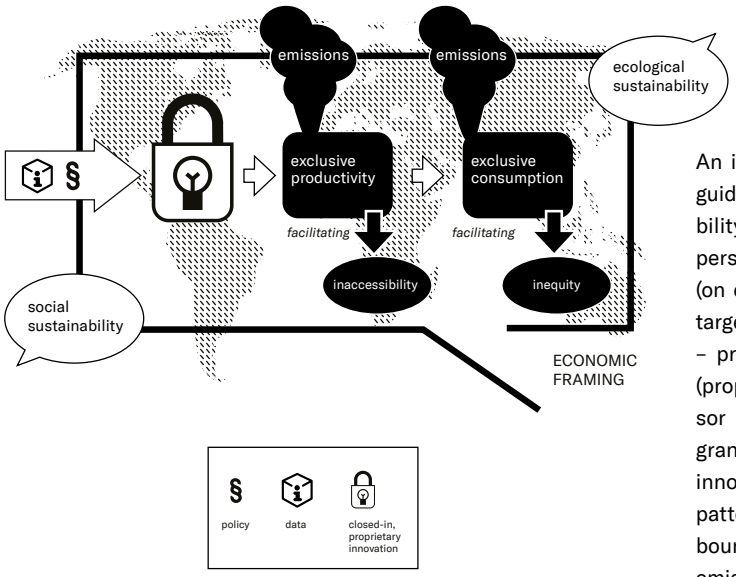
Current developments indicate individual mobility is undergoing fundamental changes that center on a mobility ecosystem fueled by data, where different modes of transport are linked and services rather than products determine mobility, the unit being the journey not the vehicle [11] or operator. For traditional ownership to make way for such an "Open Internet of Mobility (IoM)" [12], digital platforms will need to be established to optimize the use of resources, adapt to travelers' needs and, therefore, have the potential to increase not only efficiency but also sustainability [4] as they foster shared mobility, for example. A core requirement for this to happen is the Open Source paradigm for digitalization, including:

→ a networked digital infrastructure,
→ the establishment of trustworthy and accessible travel databases and
→ open application programming interfaces (APIs) for easy access.

In terms of the public value generated by such 'smart' or digital mobility solutions careful interventions are also required for ensuring an appropriate degree of equity and non-discrimination in access to these offerings, for example.

Image 2

Blackboxing Innovation in the Digital Age



An illustration of how development and innovation that is guided by the black-box principle facilitates inaccessibility and inequity in a societal, environmental and global perspective. The process can be envisioned as follows: Data (on e.g. mobility) and respective policies (for e.g. emission targets or mobility behavior) enter a fixed economic frame – profit-based – and inform / lead to closed innovations (proprietary) in that domain which then will be implemented sor produced under exclusive (legal) conditions, without granting access to other parties (e.g. other providers or innovators). This is followed by similar consumption /usage patterns, allowing only a specific group (beyond a monetary boundary) to take advantage of the initial innovation. The emissions produced during the process are black-boxed / unknown to the wider public and will exceed the set economic frame (e.g. CO_2 tax) in relation to ecological sustainability demands that come in from outside the black-box.

11 Examples include multimodal mobility such as the shift toward 'Mobility as a Service' (MaaS), meaning the ability to purchase access rights to an interoperable package of mobility services (car, taxi, bus, rail, bike share) owned by others, and automated transportation that does not require 'driving' by any of the passengers.

12 This is a framework cited by TravelSpirit (UK) for enabling MaaS integration for all mobility service providers and users opening the mobility service marketplace, democratizing access between users and service providers, and integrating new mobility services with existing transport infrastructure. A practice example of creating such an IoM integrating blockchain technology can be found here.

Our Vision: Rethinking Innovation in Mobility along the Digital Transformation toward Open Source as Default

"The past holds limited information about the future", is a statement in a European Commission report by the RISE group [13] for characterizing the current developments in the nature of research and innovation. Small, incremental changes in the way that innovation is governed based on examinations and extrapolations of data from the past will lock the global development into a path dependent process. Such governance is not able to respond to grand environmental and societal challenges, impacted vastly by digitalization, urbanization, and demographic changes. Science fiction writer William Gibson put it this way: "The future is already here - it's just not very evenly distributed". We need to reinvent the innovation trajectory from the exclusive, locked-in mode of a first world knowledge economy (see Image 2) to an inclusive, open collaboration dynamic. This vision of innovation and development is what we label as the Open Source Innovation Ecosystem (see Image 3) that can be applied in the transportation sector and beyond. The Open Source Paradigm reflects an understanding of free access to the source, remixing, redistributing, and non-proprietary collaboration. Within this paradigm, the facilitation of accessible, relevant data is oftentimes crucial as digital services and solutions depend on these. Open Source as default combined with Open Data schemes, not only inspires innovation, but may also improve public services through third party collaboration, and learning between government agencies, businesses, and the public.

Open Government as a Blueprint for Open Mobility?

The facilitation of Open Data in initiatives such as Open Government has seen a growing emphasis both in absolute numbers and in percentage among countries participating in the Open Government Partnership [14]. The availability of Open Government Data not only brings information to citizens, but also enables them to engage in decision-making processes. This can empower citizens to become agents of social transformation by monitoring and overseeing government actions and public policies. The positive impact of Open Data schemes within strands of Open Government has been studied in the ongoing project Open Data's Impact developed by New York's GovLab. According to their repository, Open Data is improving governments primarily by tackling corruption, increasing transparency, and enhancing public services and resources. Denmark's Open Address Data Set, for example, resulted in direct financial benefits through improved government back-end capabilities and more efficient service delivery as well as non-financial benefits such as improved response accuracy for the emergency services within Denmark [15]. Even though context conditions for the business case driven mobility domain may be more complex as the example above, some developments are already taking the same direction: Singapore's Government Technology Agency (GovTech) offers, next to a comprehensive

13 **Directorate-General for Research and Innovation (2018).** *Europe's Future. Open Innovation, Open Science, Open to the World – Reflections of the Research, Innovation and Science Policy Experts (RISE) High Level Group*, **p 126. doi.org/10.2777/348700**

14 **Open Government Partnership (2018).** *Year in Review 2017. Renewed Promise in Challenging Times*. **Available: https://www.opengovpartnership.org/sites/default/files/OGP_Year-Review_20180504.pdf**

15 **McMurren, J., Verhulst, S., Young, A. (2016).** *Denmark's Open Address Data Set. Consolidating and Freeing-Up Address Data. Open Data's Impact*. **Available: http://odimpact.org/files/case-study-denmark.pdf**

Open Data platform (e.g. covering Taxi-Availability in real-time), Beeline, an open, cloud-based smart mobility platform developed to provide data-driven shuttle bus services for commuters. Bus routes offered through Beeline are adaptive in so far as new routes are activated based on commuters' demand and existing routes may evolve over time. Designed on an open API architecture, Beeline allows for private transport operators and tech startups to easily integrate with the platform and build their own applications to offer more convenient transportation options for citizens [16]. Beeline's hometown of Singapore is a hotspot for shared transportation, the national Land and Transport Authority envisions in its masterplan a land transport system in 2040 where public, active and shared transport modes are so convenient that they have become the preferred choice for commuters, accounting for 9 in 10 of all peak-period journeys [17]. The transport agency is "embracing disruptions" [18] through demarcated areas for dockless bike sharing and "light touch" regulation of third-party point-to-point journey applications such as Go-Jek or GrabShare, for example. However, making the respective transportation data of such third-party providers accessible and open is far from being asserted.

Producing Open Resources in Mobility

To go about our vision of an Open Source Ecosystem, more changes in the networks of actors, resources, and power as well as a data sharing and securing culture need to be established and reflected in policies as well as experimentations. Furthermore, a renegotiation of how public value is made accessible through a paradigm shift from black boxing [19] to open sourcing is due as traditional logics of production and consumption that are going to be challenged, especially in the mobility domain where data sovereignty is the currency for business. The EU has backed its support of openness and Open Source in its digital strategy by adhering to policymaking through shared platforms and shared open-data solutions as well as transparency and collaborative working practices. However, innovations actually disrupting mobility today "are not in contact with a public structure neither at national nor at the European level" [20]. La Fabrique Mobilités (FabMob), a network of Open Source pioneers which the Open Source Lab is part of, rather suggests to allocate parts of public funds to support innovation in producing open resources, useful to all entrepreneurs and for co-innovating on new solutions. This postulation is fundamental for the mobility domain, allowing people to have considerably more possibilities to influence and access services and products (by e.g. shared mobility platforms). The analogue

16 see: https://www.tech.gov.sg/products-and-services/beeline/

17 "The Land Transport Master Plan", Land Transport Authority Singapore, press release, February 15, 2019. Available: https://www.lta.gov.sg/apps/news/page.aspx?c=2&id=16ad1e03-0b1c-45d4-a6ca-88c7e494716c

18 "Future Mobility in Singapore – Turning Disruptions into Opportunities", Yap, J. (Land and Transport Authority Singapore) presented at Australian Transport Summit August 18, 2017. Available: http://www.ttf.org.au/wp-content/uploads/2017/09/YAP-Future-Mobility-in-Singapore-Turning-Disruptions-into-Opportunities.pdf

19 Black boxing is "the way scientific and technical work is made invisible by its own success. When a machine runs efficiently, when a matter of fact is settled, one needs to focus only on its inputs and outputs and not on its internal complexity" in: Bruno Latour (1999). *Pandora's hope: essays on the reality of science studies*, Cambridge, Massachusetts: Harvard University Press. p. 304.

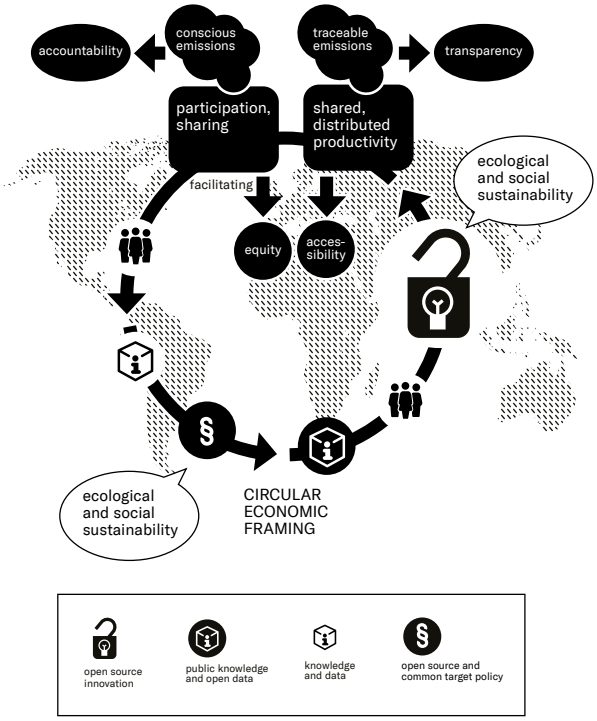
20 "Open Source for changing mobility across Europe", White Paper by Plassat, G. (FabMob). Available: https://docs.google.com/document/d/19AapYTpOYb1YsWwUrJreNBBrNPthRgkG8ZVY9t3ppUg/edit?usp=sharing

and digital world are potentially able to create new alliances and data networks impacting not only physical mobility behavior but our society at large.

A potential pathway of an Open Source approach in mobility could be as follows:

1. open access to anonymized mobility-related data for third party actors beyond silos,
2. enrichment of this data to demand-based, high quality services benefiting the public at large,
3. scaling up sustainable solutions in fast forward with fewer legal barriers and lower cost for encouraging reuse.

Image 3 **Rescaling Digital Innovation Logic: Open Source Innovation Ecosystem**



An illustration of how development and innovation that is guided by the black-box principle oftentimes facilitates inaccessibility and inequity in a societal, environmental, and global perspective. The process can be envisioned as follows: Data (e.g. on mobility) and respective policies (e.g. for emission targets or mobility behavior) enter a fixed economic frame – profit-based – and inform/lead to closed innovations (proprietary) in that domain that then will be implemented/produced under exclusive (legal) conditions, without granting access to other parties (e.g. other providers or innovators). This is followed by similar consumption/usage patterns, allowing only a specific group (beyond a monetary boundary) to take advantage of the initial innovation. The emissions produced during the process are black-boxed/unknown to the wider public and will exceed the set economic frame (e.g. CO_2 tax) in relation to the ecological sustainability demands that come in from outside the black-box.

Sustainability at Stake?

Digitalization can help optimize an entire sector like transport. Information and communications technology (ICT) allows for solutions that can contribute to reducing the global environmental footprint, through CO_2 abatement and resource savings. According to the Global e-Sustainability Initiative, ICT-enabled solutions offer the potential to generate CO_2 abatement of around 12 Gt by 2030. For the mobility sector, the same report estimates that connected private transportation, optimized traffic flows, and smart logistics could help reduce CO_2 emissions by 3.8 Gt, including savings by avoided travel from other activities, such as e-work, e-health, and e-learning [21]. There have been global efforts of evaluating mobility in cities more generally with a set of indicators covering the three dimensions of sustainability (economic, social, environmental) as well as the mobility system performance. A

21 **GeSi, Boston Consulting Group, (2015).** *#SMARTer2030 – ICT Solutions for 21st Century Challenges*. **Chapter Environment. Available: http://smarter2030.gesi.org/downloads/Chapter_Environment.pdf**

World Business Council for Sustainable Development (WBCSD) project wants to promote the use of 19 data-based indicators to enable cities to look at mobility objectively and comprehensively. Along indicators such as

→ affordability of public transport for the poorest group,
→ fatalities,
→ access to mobility services,
→ intermodal integration,
→ accessibility for mobility-impaired groups,
→ mobility space usage,
→ emissions of greenhouse gases and
→ energy efficiency,

the project also developed methodologies to calculate the indicators from defined data inputs. The results are on a scale of 0-10, where 10 represents best practice from a sustainability point of view. On a spider-chart all indicators can be reviewed in relation to each other [22]. This could be a relevant tool set for determining the sustainability of mobility solutions on the city level.

Rebound Effects of Smart Mobility

A different perspective indicates that digitalization and ICT are rather generally "reshaping societal metabolism in a way that tends to rebound on global energy and resource demand: Gains in efficiency are more than outweighed by the increase in consumption due to new digital services [such as ride hailing and car sharing] or falling prices caused by more efficient production processes" (e.g. for e-scooters or ICT devices in vehicles) [23]. The rebound effects are coupled to energy and resources needed to produce and apply those efficient technologies. As the absolute number of ICT devices steadily increases, so does the resource demand for aluminum, copper, cobalt, and many other elemental substances that are widely regarded as critical and that are mined in small quantities only [24]. Consequently, there is a steady increase in e-waste, from 44.7 Mt worldwide in 2016 to prospectively more than 50 Mt in 2021 [25] — posing serious environmental issues since it contains hazardous components potentially contaminating air, water, soil, and people's health. Moreover, the share of communication technology in total global electricity consumption is increasing, from 11% in 2010 to potentially 21% or even 51% in 2030 [26]. However, chances are that, until 2030, the globally generated renewable electricity is likely to exceed the electricity demand from end users as well as from data centers, cloud services, search engines, etc. The impacts of digitalization on sustainability through efficiencies in production, consumption, communication, and everyday life are yet to be examined in order to conclude whether its potentials can prevail. In the meantime, Prof. Santarius, head of the research group "Digitalization and Sustainability" at the Technical University of Berlin,

22 **World Business Council for Sustainable Development (WBCSD) Mobility (2016).** *Integrated sustainable mobility in cities, Sustainable Mobility Project 2.0 – a practical guide*. **Available: https://docs.wbcsd.org/2016/04/Integrated_Sustainable_Mobility_Cities_practical_guide.pdf**

23 **"Digitalization, Efficiency and the Rebound Effect", Santarius, T.,** *degrowth Blog*, **February 16, 2017. Available: https://www.degrowth.info/de/2017/02/digitalization-efficiency-and-the-rebound-effect/**

24 **Manhart, A., Blepp, M., Fischer, C., Graulich, K., Prakash, S., Priess, R., Schleicher, T., Tür, M., (2016). Resource Efficiency in the ICT Sector.** *Greenpeace*. **Available: https://www.greenpeace.de/files/publications/20161109_oeko_resource_efficency_final_full-report.pdf**

25 **Baldé, C.P., Forti V., Gray, V., Kuehr, R., Stegmann, P. (2017).** *The Global E-waste Monitor – 2017.* **United Nations University (UNU), International Telecommunication Union (ITU) & International Solid Waste Association (ISWA), Bonn/Geneva/Vienna.**

26 **Andrae, A.S.G., Edler, T. (2015). On Global Electricity Usage of Communication Technology: Trends to 2030.** *Challenges* **6(1), 117–157. doi:10.3390/challe6010117**

proposes an alternative approach to framing sustainability through digitalization: “The only unambiguous way using digital technologies for sustainability reasons is not for pursuing greater efficiency, but for enabling greater sufficiency in human action and degrowth in material consumption” [23].

Social Sustainability of Data Economies

Next to environmental challenges, the socially sustainable development of the digital economy is also a crucial point to consider. A contemporary metaphor renders data as the crude oil of the 21st century. This is to say that data is as valuable, but apart from that, the analogy is rather misleading. For data, there is no natural scarcity, meaning that they can be reproduced endlessly and are, therefore, inexhaustible. Currently, only limitations in capacity are encountered when it comes to collecting, storing, and processing data. The arising questions of social sustainability concerning data use are more pressing. “Digital Fair Trade” [27] s a phrase referring to data use for common good, where the user is included in the data value chain. A fair digital value chain depends largely on regulatory framework conditions for e.g. data sovereignty, data rights and control. Privacy Information Management technologies (PIMS) like digi.me or MyData work on providing users with full data control in one place and the possibility for them to predefine their privacy preferences [28]. Chances are blockchain technology — such as Smart Contracts – can leverage the management of data rights and their fair distribution among different stakeholders [29]. This is a critical point for data-driven mobility solutions and mobility stakeholders will have to relate to this issue more genuinely.

One path in taking the fair data ecosystem further is the idea of data collectives. As the name implies, these are coalitions of companies, aiming at economically or socially advancing their members through shared business operations, such as fairly distributing the added value from the digital value chain process [30]. Special interest or sectoral data collectives (for e.g. mobility) could enable a broader participation in knowledge gains through data analysis and thereby provide a more sustainable framework for the data economy. The model of commons for data (e.g. Wikipedia), closely connected to Open Data policies, plays a similarly important role in leveraging sustainability of emerging collaborative platforms (e.g. ride sharing) as well as of economic platforms (such as Uber or Airbnb for accommodation).

27 **Horn, N., Reinhardt, M. (2018). Datenhoheit – Gerechtigkeitsfrage in einer Digitalen Gesellschaft.** *Denkimpuls innovativer Staat*, **Version 1, October 8, 2018. Available: https://initiatived21.de/app/uploads/2018/10/denkimpuls_datenhoheit.pdf**

28 **Foundation for Data Protection (Stiftung Datenschutz) (2017). New ways of providing consent in data protection – technical, legal and economic challenges.** *Policy Paper*, **Leipzig, Germany. Available: https://stiftungdatenschutz.org/fileadmin/Redaktion/Bilder/Abschluss_Studie_30032017/stiftungdatenschutz_PolicyPaper_New_ways_of_providing_consent_in_data_protection_EN_final.pdf**

29 **For an example see MADANA.**

30 **“Die Facebook-Genossenschaft”, Naumer, H.J.,** *makronom.de*, **April 4, 2018. Available: https://makronom.de/netzoekonomie-datenschutz-informationelle-selbstbestimmung-die-facebook-genossenschaft-25926**

Added Value through Open Source Super Powers

Against the presumptions of early theoreticians that "every agent is actuated only by self-interest" [31], Open Source projects and open collaboration with or without Open Data policies have been gaining traction also in economic contexts. When "managed effectively (i.e., with an optimum of planning), open source can lower barriers to innovation and increase the effectiveness of collaboration, enabling continued positive economic growth" [32]. In mainstream economic theory, the firm or modern corporation has often been described as a black box, meaning that internal arrangements within organizations have largely been ignored or treated as sealed-in mechanisms. This is changing: "Business as Mutual" [33] is the unusual mission statement of **OpenDesk**, a furniture company following an open business model with distributed local manufacturing (through a network of local independent businesses) instead of traditional, transport intense mass production. IT companies like Mozilla or Red Hat — also known as the "Open Organization" [34] — have been practicing an Open Source approach throughout their business very successfully [35] since the early 1990s.

The reason to regard Open Source as a super power is transparency and, therefore, reliability and security. Open Source implies that all of the code within some workflow is completely visible to the users. There are no hidden processes or black boxes [9]. Furthermore, enabling Open Source developments or solutions fueled specifically by Open Data has beneficial aspects for society [36]:

- → new forms of social mobilization (e.g. in favor of better bicycle infrastructure), both in turn facilitated by new ways of communicating (users as developers) and accessing information
- → job creation (e.g. new demand-driven mobility services)
- → solving public problems by allowing citizens and policymakers access to new forms of data-driven assessment of the problems at hand as well as data-driven engagement producing more targeted interventions and enhanced collaboration (e.g. for commuting times and peak time hurdles).

With or without Open Data policies, Open Source projects are both a platform for doing public good and a viable business model. "While the idea of open source projects prospering only through voluntary contributions is romantic, in reality, the majority of open source contributions are done through paid development" [37]. More and more, an increase in decentralized micro-funding of self-sustaining Open Source projects can be observed. Open Source

31 **Edgeworth, F.Y. (1881).** *Mathematical Psychics: An Essay on the Application of Mathematics to the Moral Sciences*, **New York: A. M. Kelley, p 16.**

32 **"The (awesome) economics of open source", Tiemann, M. in** *opensource.com*, **2018, September 13. Available: https://opensource.com/article/18/9/awesome-economics-open-source?utm_campaign=intrel**

33 **https://www.opendesk.cc/blog/from-business-as-usual-to-business-as-mutual**

34 **Whitehurst, J. (2015).** *The open organization – igniting passion and performance*. **Boston: Harvard Business Review Press.**

35 **Red Hat with an open, collaborative business model for software development has been raising their annual revenue constantly throughout the last 10 years, see "Fast Facts" on https://www.redhat.com/en/about/company**

36 **http://odimpact.org**

37 **"How blockchain will influence open source", Ibryam, B.,** *opensource.com*, **August 2, 2018. Available: https://opensource.com/article/18/8/open-source-tokenomics**

funding platforms allow individuals through bug bounties, micro-payments, recurring donations, one-time contributions, subscriptions, etc. to take responsibility for Open Source sustainability in their own hands by paying maintainers directly [38]. This enables a relationship between developers and users that has not existed before and goes beyond charity.

Open Source Mobility Success Story: Finland's Digitransit

The transport industry is undergoing a significant digital disruption. Thanks, in part, to high profile success stories, the transport industry is beginning to see the potential opportunities of open ecosystems (open datasets and unified APIs) that enable Open Source software development. One such example is the collaboration of Helsinki Regional Transport Authority (HSL), the Finnish Transport Agency, and other Finnish cities to create Digitransit [39], a platform providing OpenTripPlanner-based trip planners, APIs, Open Data, Docker containers and Open Source code, including a custom user interface (UI), available on GitHub, the largest repository of source code in the world. The Digitransit system also has a strong real-time component such as HSL's real-time public transport vehicle location data. Next to a journey planner HLS also created OpenMaaS [40], an open-for-all ticket sales interface for acquiring public transport mobile tickets.

By providing the Digitransit platform HLS is improving journeys, saving people time, supporting innovation, lowering barriers to new businesses and creating jobs. In fact, Digitransit has already gained momentum: The Metropolitan Transportation Authority (MTA) of New York and the Norwegian Public Roads Administration have deployed their own localized versions based on Digitransit [41].

Potentials of the Open Source Paradigm in Mobility

Numerous Open Source projects and resources reflect the immense potential of Open Source in the automotive and broader mobility field ranging from global private associations like Bloomberg's SharedStreets to public actors like the World Bank's OpenTraffic. Many endeavors have come to terms with the "super powers of open source" [20] generating benefits on several levels ranging from improved brand image, over creating spaces for non-competitive dialogues, to accelerating and delivering solutions faster. Open Source assets can play a key role in reducing barriers for entrepreneurs, in concentrating research progress on common platforms producing standards, but also in improving links and connections between all stakeholders – public and private. Consequently, open assets can be considered as a way to accelerate innovation in complex ecosystems with high numbers of heterogeneous stakeholders. Actors such as FabMob from France foster such heterogeneous groups of Open Source pioneers working to produce solutions (from energy to vehicles), bringing in added value by cooperating and interacting in order to deliver new and open mobility solutions. Such transition addresses technologies, industries but also culture. The Open Source way proves to be a liberating voice for the future, not only in the IT-domain, as it inspires diversity in perspectives as well as in people.

38 https://opencollective.com

39 https://www.europeandataportal.eu/en/news/open-mobility-service-helsinki

40 https://sales-api.hsl.fi/

41 https://www.databusiness.fi/en/News/digitransit-free-and-open-source-journey-planner-for-cities/

Potential benefits [42] of applying the Open Source paradigm in mobility solutions include:

→ Improving the quality of mobility services through amplified or expanded involvement from the outside.
→ Providing a framework for collaboration and removing legal and economic barriers across the fragmented mobility sector.
→ Allowing transparency to customers, partners, and mobility providers and businesses through process transparency and documentation.
→ Viewing Open Source in mobility services and solutions as a form of insurance through broad contribution which allows for third parties to have more routes by which to procure functional support.
→ Stopping monopolistic entities from establishing early dominance in a particular area of mobility (e.g. electric vehicle (EV) charging or ride hailing) as Open Source can spread so quickly and gain a significant share of the user base.
→ Engaging with users (also seen as developers) of mobility services as a very effective way to learn about the demands and preferences.
→ Leading a standardization effort (e.g. for EV charging policies or emission monitoring)

Challenges for the Development of an Open Source Innovation Ecosystem

"Open Source has grown from a small, academic sharing network to a giant, global web of dependencies. It now forms the backbone of the internet and technology in general. Just like any growing city, we have to coordinate the knowledge, infrastructure, and tools for the good of the whole community" [43]. Even though there is clear evidence of significant positive outcomes and benefits of an Open Source approach in mobility, most of the time the results of such projects and their impact are anecdotal and qualitative in nature. In addition, while there is substantial data on the performance of transit systems as well as Open Data availability and use, the links to the outcomes of interest [44], for creating a sense of relevance and of public value, are poorly defined or understood. The quantitative data that is available does not always help with indirect measures of outcomes. Cities suffer from a lack of awareness on the benefits of Open Data in the mobility domain: they find it difficult to convince data holders to release their data, since an "Open by default" approach is not yet common across this particular sector [45]. Open Source Innovation is primarily data-driven and the largest Internet enterprises like Google and Amazon have a rather monopolistic share of the global data market, smaller entrepreneurs, startups, NGOs, and civil society have a worrisome starting position in this environment. Through the opening of data by large companies

42 This section was informed by The Mozilla Foundation and Open Tech Strategies "Open Source Archetypes: A Framework For Purposeful Open Source", 2018. Available: https://blog.mozilla.org/wp-content/uploads/2018/05/MZOTS_OS_Archetypes_report_ext_scr.pdf

43 "Let's talk about open source sustainability", Zuegel, D. in *GitHub Blog* Community, 2019, January 17. Available: https://github.blog/2019-01-17-lets-talk-about-open-source-sustainability/

44 Dell (2018). Driving Positive Outcomes through Open Data Solutions for Mobility, *Report*, February 2018. Available: https://i.dell.com/sites/doccontent/corporate/corp-comm/en/Documents/mobility-open-data.pdf?newtab=true

45 Berends, J., Carrara, W., Vollers, H. (2017). Analytical Report 6: Open Data in Cities 2. *European Data Portal*, June 2017. Available: https://www.europeandataportal.eu/sites/default/files/edp_analytical_report_n6_-_open_data_in_cities_2_-_final-clean.pdf

to smaller competitors or other third parties, as Oxford professor Viktor Mayer-Schönberger [46] proposes, the powers of innovation could truly be unleashed throughout the mobility domain, as diversity in the market would flourish.

Barriers for Open Source Innovation in mobility are found within the political, organizational, legal, technical, and financial domain, and low awareness on both the availability of mobility related data and the specific needs of users of data and respectively Open Source contributors (e.g. developers) leaves room for improvement. Some challenging aspects are:

→ **Low awareness** on data sharing in the public as well as for data holders (e.g. industry) as it is an abstract issue with **unclear benefits** to everyday life or to business.

→ Growing **concerns on issues of privacy**, security, anonymization and consent.

→ **Faltering support** as views on the benefits of sharing data and open collaboration are not universally shared within organizations and between potential re-users.

→ **Poor quality of data and the automation** associated with uploading and updating datasets related to the lack of skills of the people working in those departments (e.g. local municipalities) or businesses where the data is produced. This results in data not being complete, not being correct or not being updated on time.

→ **Additional financial resources** are needed in order to release and publish mobility data. For most businesses and even some government departments moving towards Open Data would mean losing a source of revenue as they would have to stop charging for data that they make available [47].

→ **Financial considerations on the developer site** (e.g. start-ups) also play a role as it will need a positive business case. Although e.g. Open Data is available for free, using it and packaging it into an application may require an investment.

→ **Digital divide challenges** generally arise by disproportionally benefiting elites of society that have data science capabilities [48].

Open Source Mobility Theses

Rather than focusing on the technical aspect of transport, meaning the efficiency of vehicular movement of people and goods, the Open Source Lab adopts a broader understanding of mobility according to traffic sociology, as a "basic condition for access to amenities, information and services, which has to be guaranteed politically, socially and economically" [49].

This view enables us to see Open Source as a catalyst for sustainable transformation, aiming at governing digitalization to provide means of innovation to everyone. As a think tank, the Open Source Lab takes up the concept of 'Open Source Mobility' and facilitates it as a discussion platform – a node in the vast network of innovators and pioneers already working on a sustainable future.

46 **Mayer-Schonberger, V. and Ramge, T. (2018)** *Reinventing Capitalism in the Age of Big Data*. **Hachette UK**

47 **Berends, J., Carrara, W., Vollers, H. (2017). Analytical Report 5: Barriers in working with Open Data.** *European Data Portal,* **March 2017. Available: https://www.europeandataportal.eu/sites/default/files/edp_analytical_report_n5_-_barriers_in_open_data.pdf**

48 **"Open Data: Empowering the empowered or effective data use for everyone?", Gurstein, M.,** *First Monday*, **February 2011. Available: http://firstmonday.org/article/view/3316/2764**

49 **Rammler, S. (2016). Progress through Mobility, in W.I.R.E. (Eds),** *ABSTRACT* **No. 15 — Transforming Transport, Zürich: Neue Züricher Zeitung Publishing, p 15.**

On the basis of our initial research and expert discussions, we have formulated theses that aim at deepening the exchange and discussion in the field:

1. Open Source by Default for Driving Sustainability

The Open Source paradigm needs to be the key characteristic of digitalization across sectors, making this mega trend a driving force for sustainability in the mobility domain. Core requirement for optimized resource use, adaptation to user's needs and increased efficiency is the development of a networked infrastructure and the establishment of databases to feed digital mobility platforms. In this environment, vivid Open Source software communities of developers and contributors may create diverse mobility related digital services. Such an open ecosystem of mobility, which combines "Digital Fair Trade" and Open Data, has the potential to outdate ownership. On top of that it would create a "level playing field" of openness which would alter business approaches. If all businesses have to be open then profitability would not be contingent on secrecy but on better service delivery.

2. Data Literacy for Growing a Data Sharing Culture

For digitalization to become a sustainability agent, a mature Data Sharing Culture needs to be fostered by authorities, corporates, and civil society. Governments and civil institutions should, preceding the evolution of a sharing culture, put great emphasis on data education and literacy. Informing the public about data, data privacy, and data control ("Digital Sovereignty") will enable an ecosystem of real-time data — or data commons — to be used for policies as well as open source applications, services and products. This not only allows for a comprehensive understanding of user behavior, but also opens doors for bottom-up solutions (such as mobility collectives) and small competitors to innovate and change the market radically.

3. Embedded intelligent Mobility

Change cannot rest upon volunteers. Intelligent mobility needs to be embedded in the expanded framework conditions of the economy and society. Mobility innovations – in the analogue or digital realm — need to shift the focus away from single solution or stand-alone products to the intelligent linking of transport, space, and population. With more imagination exercised, such a social and economic framework could for example include for employers to enable employees to work, be it by a sustainable commuting provision or by a remote-working scheme. A framework that includes the aspects of mobility can also steer the proportions of individual mobility needed and thus lead to sustainable outcomes.

4. Public Value in Public Transport

The focus of innovations in the overburdened transport system needs to shift from efficiency (moving more people in a shorter amount of time for less cost) to sufficiency and added value for users (or public value at large). Design will play a major role in the transportation sector as one of the key differentiation factors for mobility behavior. This includes strengthening social functions of transport, such as trains and busses. Social interaction, relaxation, or concentrated work can be seen as added values for the users as the traveling time is rendered useful and inspires human-centric designs.

An Outlook: Policy Recommendations and Research Gaps

With our network of Open Source pioneers, we are working toward certain actions allocated in the political and policy domain. These hold the potential not only to foster further collaborations throughout the network but also to engage more and more stakeholders in the debate on and the design of our future:

→ Integrating the production of Open Source resources (e.g. Open Data, open APIs) in publicly (e.g. European Commission) financed projects at national and European levels.
→ Debating framework conditions of economy and society with a medium to long-term perspective and being open to unconventional disruptions.
→ Gearing innovation in mobility to people by putting people's future needs as basis for development and allowing for civic participation through open source policies with accessible data and “Digital Fair Trade”.
→ Legislation compelling public and private transport operators to make mobility-related data accessible through e.g. operating licenses contingent. As well as breaking apart data monopolies of large companies in mobility (automotive industry, web-based navigation and location) by assigning representative anonymized data sharing obligations when a fixed market share is exceeded to provide mobility related data for open platforms.
→ Creating personal mobility accounts with clear and easy-to-use interfaces to reduce the data flood for users, raise the quality of transport data, enable data sharing and build consciousness about relations between mobility behavior and emissions.
→ Ensuring data security and transparency in new business models (e.g. collectives) by setting specific standards on an ethical and technical level to ensure trustworthiness, and incentivizing data sharing through real user benefits. Underlining the importance of a continuous dialogue between data users and data holders, to stimulate both the publication and the reuse of data.
→ Establishing public platforms for running pilots and experiments, allowing small, completely new ideas to be scaled up when successful.
→ Merging public and individual transport thus raising the quality of public transport for users and allowing for publicly regulated measures.
→ Institutionalizing the publication (governance model) of Open Data in the mobility domain, making it an integral part of the data creation process, rather than a separate or additional activity to the daily operational processes and routines.

Research on the impact of Open Source Innovation and Open Data or data sharing policies supports the “business case” for future funding and implementation. Impact of such policies can be political, social, and economic. Political impact refers to government efficiency, effectiveness, and transparency, while the social impact for instance refers to environmental sustainability and social inclusiveness. Economic impact refers to economic growth, business innovation, and job creation. Concludingly, we also see research activities ahead which need to be tackled:

→ collect best practice examples of open source policies and their development,
→ analyze the deficiencies of open source projects and Open Data policies in mobility,

→ co-create business models and public interest in open source mobility solutions,
→ developing and testing tools to enable public access and contribution to open source mobility assets (e.g. data commons and data collectives),
→ more user research (needs and constituencies) in the mobility domain with emphasis on cause and context (away from symptoms such as e.g. traffic congestion),
→ explore ways to implement data literacy into a global knowledge culture,
→ measure the impact of digital solutions in mobility in terms of sustainability,
→ reconceptualize digitalization to serve a sufficiency revolution in mobility.

The purpose of the Open Source Lab Sustainable Mobility is to build up a platform to enable interdisciplinary research and a broad dialogue on sustainable mobility by involving various relevant stakeholder groups.

The Open Source Lab stands for
→ Open Source as a working principle
→ Interdisciplinary research on the interface between sustainable mobility and open source concepts
→ close collaboration and content-related exchange with the VW Sustainability Council and relevant stakeholders
→ broad impact through research papers and low-threshold dialogue formats from experts to everyday consumers

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open source lab

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