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Data-Driven Micromobility Governance – A Stage Model

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Data-Driven Micromobility Governance – A Stage Model

Research Paper

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Abstract. City authorities are faced with aversions of traditional traffic participants to shared micromobility services albeit these were deemed as a cornerstone of sustainable urban transportation. At the same time, the connectivity of shared vehicles, i.e. bicycles and e-scooters, should allow city authorities to design smart transportation policies. We investigate how cities can and do use micromobility data to reduce aversion and increase the sustainability of personal transportation. Applying design science research, combining knowledge from literature and expert interviews, we derive ten objectives of data-driven micromobility governance. We present and discuss these objectives in a stage model with five maturity levels. Our stage model includes benefits for citizen acceptance, prerequisites for implementation, and provides an actionable agenda for theory and practice.

Keywords: Micromobility, Smart city, Stage model, Big data, Maturity model

1 Introduction

City authorities are adopting Information and Communication Technology (ICT) to become smart sustainable cities. One central aim is to increase the quality of life of citizens through smart urban transportation. ICT can collect personal transportation data, citizen sentiment data about services, and assist in managing traffic (Sarker, 2022).

Within the aspect of smart urban transportation, shared micromobility was introduced as a sustainable and disruptive service (Kendziorra *et al.*, 2023). Promises were among other reduced numbers of private car trips and more convenience on the last mile of public transport. The digital nature of shared micromobility services provides the opportunity to gather data to providers, researchers, and governments, to examine the impact and manage the usage of this new personal transportation service (Fitt and Curl, 2020) and to interact with users and citizens (Gössling, 2020).

However, e-scooter ridership in particular has currently a strong negative effect on the traffic satisfaction of city inhabitants moving by car, bicycle or foot (ADAC, 2023). Gössling (2020) stated to mitigate the negative sentiment about shared micromobility, city authorities must carefully intervene and manage the disruptive changes associated with it. They must manage power struggles, social and cultural resistance, and infrastructural as well as technological challenges. To do so, some authorities have implemented policies and expanded their ICTs to cover micromobility (Gössling, 2020).

But research has called for more sophisticated interventions to promote this sustainable mode of transport, e.g. joint booking and tariff systems (Schumann, Haitao and Quddus, 2023). Public organizations aiming to intervene must adapt to innovation and recognize particular challenges. Practitioners face pressure to deliver innovative services with limited human and funding resources as well as being trained for acquisition processes in which expectations and requirements are defined upfront (Jiang *et al.*, 2022; Mergel, 2018). It poses the question how city authorities can identify, prioritize, and implement data-driven ICT objectives that mitigate the negative impacts and leverage the strengths of this new type of mobility. In the literature we found little on how city authorities use micromobility data or challenges they face while implementing interventions. Sochor *et al.* (2018) have proposed a five stages model of Mobility-as-a-Service (MaaS) integration. Apart from that we only found in the grey literature Laborda (2022) building on this research and suggesting a five level maturity model of data-led micromobility management derived from MaaS integration levels.

Maturity and stage models are common to assess the quality of an organization its goods and services, to identify solutions for change, and to improve its competitiveness. They "serve to solve the problems of determining a company’s status quo of its capabilities and deriving measures for improvement therefrom" (Becker, Knackstedt and Pöppelbuß, 2009, p. 214). Stage models help organizations to effectively manage resources and to achieve complex objectives with acceptable levels of risk. They assist in establishing priorities and provide guidelines (Gomes, Romão and Calderia, 2013). The stages particularly allow for a systematic understanding of the inherent effectiveness and value of different stages of growth, creating awareness on the importance, potentials, requirements, and complexity. Thus, through stage models public administrators can decide on themselves which stage is best for their situation (Wendler, 2012).

We hence develop a stage model of data-driven micromobility governance to identify the value for citizens and requirements of the derived objectives. We build upon Lee (2010) who proposed a common frame of reference for e-Government stage models. We selected this reference frame, as it evolves around the role and involvement of citizens while including technological and operational requirements. To research the maturity of micromobility data usage in public authorities, to derive an actionable agenda for the continuous improvement of city governments, and to identify opportunities for further research we formulate our Research Question (RQ) as

"How can city authorities prioritize micromobility data utilization based on capabilities needed and value provided to adapt to disruptions caused by micromobility?"

To address our RQ, we apply a Design Science Research (DSR) approach, following Doyle, Luczak-Roesch, and Mittal (2019). Using DSR for the development of maturity models is proposed by Becker, Knackstedt, and Pöppelbuß (2009). We combine theoretical knowledge about data utilization and sustainability aspects from literature with practical knowledge from different experts in this field. We deduce and classify our findings along the five stages of Lee (2010), adapt the reference stage model and present a novel artifact that contributes prescriptive and descriptive knowledge to realize the potential of smart urban transportation and further research opportunities. We then discuss our findings and give recommendations.

2 Research Design and Methods

To address the RQ, we design and evaluate a new artifact following Doyle, Luczak-Roesch, and Mittal (2019). Becker, Knackstedt, and Pöppelbuß (2009) suggest to use DSR. Table 1 shows the 6-step research process to formulate the stage model that serves descriptive and prescriptive purposes and to discuss the findings (Becker *et al.*, 2010).

For Step 1, the problem identification, Becker, Knackstedt, and Pöppelbuß (2009) state three requirements: "the artifact must be relevant to the solution of a heretofore unsolved and important business problem" (Peffers *et al.*, 2007, p. 49), must contribute to current research, and the novel model must be substantiated by comparison with existing models and might be an improvement of a known maturity model. We motivate our research in the Introduction and reflect on current research in Section 3 to elaborate on the relevance of our research and existing maturity models.
In Step 2, the literature search, we applied filters to ensure a feasible number of results (vom Brocke *et al.*, 2015). We limited the search to a basket of high-quality journals focusing on transportation, i.e. the Journal of Transport Geography, Transport Reviews, Travel Behavior and Society, and Transportation Research Part A, B, C, D, E, and F. We searched the basket with the search string "shared micromobility" in title, abstract, or keywords and date of publication between 2018 and 2024. In consecutive order the title, abstract, and full-text were evaluated. Literature was deemed relevant and included, if it provided information on an aspect of data-driven government in the context of micromobility and livability or sustainability. We screened in total 152 papers out of which 42 were considered relevant based on the full text. The search protocol can be found in the online appendix. As suggested by Webster and Watson (2002), we developed a concept matrix of the relevant literature in Step 3. Concepts were filtered out if they did not fit to the RQ, e.g., COVID-19 impacts on demand.

Table 1. Research design

DSR Steps		Results	Sources
Problem	**Step 1:** Identify problem	Research motivation	(Becker, Knackstedt and Pöppelbuß, 2009)
Design and build the artifact	**Step 2:** Literature search	42 relevant papers	(vom Brocke *et al.*, 2015; Webster and Watson, 2002)
	Step 3: Deduce concepts	10 prescriptive concepts	
	Step 4: Expert interviews	12 expert interviews	(Franzke and Zeitner, 2023; Mayring, 2015; Röglinger, Pöppelbuß and Becker, 2012; Schultze and Avital, 2011)
	Step 5: Finalizing artifact	Stage model	
Evaluation	**Step 6:** Evaluation of artifact	Evaluated stage model	(Schoormann *et al.*, 2024)

After the literature search, we conducted twelve semi-structured interviews in Step 4 to derive practical knowledge. We choose anonymized, semi-structured interviews to engage subjects in a conversation and to get a first-person account of the participant's reality (Schultze and Avital, 2011). Following Mayring (2015), we gathered and later structured questions along the theoretic concepts deduced from our literature search. The interview guideline can as well be found in the online appendix. We conducted interviews until saturation was reached (Strauss and Corbin, 1990). To validate saturation, we selected at least two interview partners from key stakeholders: City Authorities (CAs), Mobility Agencies (MAs), and Sharing Providers (SPs) ensuring that no additional data lead to new insights by adding perspectives from Research (RE), Non-Governmental Organizations (NGOs), and Consulting (CO). Information about the interview partners is displayed in Table 2. Interviews were conducted from August to October 2023, lasted between 20 to 60 minutes, were recorded, and transcribed afterwards.

In Step 5 the interview data was evaluated by following Mayring (2015). After defining the relevant material, a theory-based, deductive set of initial categories was defined. Utilizing a data sample of four interviews, definitions, anchor examples, and coding rules were adjusted to make them applicable to the data. The coding rules were then applied to the full data set. Any remarks and conflicts of the coding rules and the interview data were noted. These consecutive steps were first individually conducted and then discussed between the first and second author after each step, to achieve validity of the categories. Lastly, the full data set was revised by the first and second author to reflect on the changes. Then, following the content structuring rules of Mayring (2015), coded interview references were first paraphrased and then summarized per category to extract information. Anchor examples can be found in the online appendix.

Based on the derived practical knowledge from Step 4 and Step 5, combined with the theoretical knowledge from Step 2 and Step 3, the artifact was created. We applied the design principles for prescriptive and descriptive maturity models proposed by Röglinger, Pöppelbuß, and Becker (2012) to adapt and extend the reference stage model from Lee (2010) for the specific purpose of data-driven micromobility governance.

Lastly, evaluating the artifact is a relevant part of DSR (Gregor, Kruse and Seidel, 2020). We conducted the ex-post evaluation and justification in Step 6 based on theory as proposed by Schoormann *et al.* (2024) and used Google Scholar, its similarity search, and Research Rabbit to add additional literature to the basket that reflects on the novel findings of our interviews, and that were not covered through the initial literature search.

Table 2. Interviewed experts

Expert	Affiliation
CA1, CA2, CA3	Representatives of mobility departments in different cities (all cities have more than 500,000 inhabitants)
MA4, MA5, MA6	Employees at different government funded mobility agencies
SP7, SP8	Area managers at different micromobility sharing providers
RE9, RE10	Postdoctoral researchers on urban mobility
NGO11	Representative NGO "VCD Kreisverband Hannover Region"
CO12	Consultant for urban mobility

3 Theoretical Knowledge from Literature

3.1 Stage Models for Public Organizations and Micromobility Services

For shared micromobility and public organizations we found only a few papers that categorized maturity or service levels. Sochor *et al.* (2018) proposed a topology of 5 MaaS integration levels from no integration to integration of societal goals elaborating on responsibility management of MaaS operators on different levels and the incorporation of policy goals. At that time the authors put little emphasis on micromobility and did not include e-scooters which significantly changed the topology of MaaS offers. Later, focusing on e-scooters, Kazemzadeh and Sprei (2022) conducted a literature review and proposed a framework to measure the quality level of service and road network infrastructure based on user preferences, reflecting much on cycling literature. In the grey literature Laborda (2022) elaborated on the role of mobility data management in the context of the MaaS integration levels proposed by Sochor *et al.* (2018). Barriers for public and private mobility stakeholders are stated that must be overcome in order to unlock value, i.e. trust in data. On the lowest level integrated information is used for reporting, followed by data-driven policies, succeeded by pricing and subsidies for optimized decisions, and on the highest level societal goals of the cities' mobility plans are supported through multimodal optimization. He stated a need for policymakers to understand this new form of mobility and demanded data-informed mobility policies.

These papers focused on the objectives to improve the quality of mobility services but did not consider the aversion of non-users or emphasized little the perspective of city authorities, i.e. the capabilities needed to implement the stages. To address this gap we select the reference framework of Lee (2010). It contains the stages presenting, assimilating, reforming, morphing, and e-Governance in relation to the two themes operation/technology and citizen/service. Each stage has a focus on data usage in the context of operation/technology, benefits for citizens are covered in the theme citizen/service.

3.2 Data-Driven Micromobility Objectives

In line with the relevant literature on micromobility stage and maturity levels we found the literature on objectives from the citizen/service perspective to be underrepresented. Studies dominantly addressed how micromobility data can be used to identify trip patterns, hotspots, respective parking zones or the sustainability of personal urban transportation. To a lesser extent the results reflect on the potential interaction of citizens with governments and providers through micromobility services. Relevant findings have been made among other by Fitt and Curl (2020) who partially focus on spatial conflicts. Gössling (2020) screened newspaper reports to identify micromobility concerns reported by these outlets. In recent publications, the role of organizations has been further emphasized. Schumann, Haitao, and Quddus (2023) researched how passively generated big data can improve the safety, social impacts, environmental impacts and system design of micromobility. They suggest among other, increased sensor deployment, data-driven interventions for short-term demand adjustments, and analysis of public transport ridership data to better integrate micromobility in multimodal trip chains. Bigotte and Ferrao (2023) studied the future role of e-scooters in urban mobility for cities in Portugal by interviewing experts. We further address this gap in the later sections through the results of our expert interviews.

To comprehensively analyze the literature, we conducted a literature review an aggregated the findings as categories of objectives. We grouped the categories along the individual stages of Lee (2010). On the first stage, Presenting, scattered information is displayed. Visualizations can be positioned towards citizens/services or operation/technology, i.e. city employees, but might only be available and not processed (Lee, 2010). To reach this stage, micromobility data must be accessible, and capabilities should exist to visualize the data. The literature suggests *Visualizing Accidents and Locations* (Arias-Molinares *et al.*, 2023; Gössling, 2020), to study the positions and quantities of micromobility vehicles and respective accidents.

The second stage, Assimilating, refers to the integration of scattered information bases and applications. During this phase interaction-based services emerge that assimilate informational processes with real-world ones (Lee, 2010). Through integrated information bases *Tailored Operating Areas* can be defined based on the built environment and urban characteristics (Huo *et al.*, 2021; Karimpour, Hosseinzadeh and Kluger, 2023). *A Platform for Citizen Interaction* helps city employees, according to literature, to better manage conflicts or suggestions, e.g. services for citizens where they can report spatial conflicts caused by micromobility vehicles or users (An *et al.*, 2023).

On the third stage, Reforming, authorities reform processes and services in the real-world, re-engineer and streamline operations and technology, and start to provide digital transactions focusing on increased efficiency (Lee, 2010). City authorities can target *Hotspots* for mobility hubs, parking spaces and targeted infrastructure interventions to improve traffic safety (Arias-Molinares *et al.*, 2023; Gössling, 2020). Transactions allow the efficient provision of sharing services in one platform application by *Merging and Marketing Services from Different Providers* (Vij and Dühr, 2022).

On the fourth stage, Morphing, the scope of government activities changes as the potential of data usage and micromobility is identified. The focus shifts towards planning and developing new services for the benefit of citizens, focusing on effectiveness not only efficiency. It is expected that citizens can participate more actively in change processes compared to simple interactions and transactions (Lee, 2010). City authorities then could promote the substitution of less sustainable transport modes (de Bortoli, 2021; Fan and Harper, 2022) or make micromobility services available to disadvantaged communities (Christoforou *et al.*, 2021). *Improving Road Networks* could then be carried out in a targeted and effective manner to address citizens most willing to switch transportation means (Kazemzadeh and Sprei, 2022). Further, Citizens could request additional services through *Sustainable, User-friendly MaaS Provision* helping cities to attract or retain users (Blazanin *et al.*, 2022; Hong, Jang and Lee, 2023).

On the fifth stage, e-Governance, authorities can make use of the full capabilities of advanced ICTs, i.e. technical and operational components being reconfigured almost ad-hoc and citizens and authorities can interact in near real-time (Lee, 2010). Traffic violations can be monitored and fined precisely in near real-time through *Smart Traffic Rules Enforcement* and sharing capacities can be dynamically adapted through *Dynamic Provision* (Schumann, Haitao and Quddus, 2023).

4 Practical Knowledge from Interviews

Presenting. With regard to data availability and presentation, the reported maturity differed between cities. CA1 is in negotiations with service providers to share the data, while CA2 already has access to dashboards that monitor parked vehicles and hotspots. Consultant CO12 added: *"Some cities oblige providers to share data, others do not. Even though, general permissions give cities great leverage. A general mobility data law is also being drafted at the federal level. Then you have to share your data. That will provide added value for traffic planners and many others in the city."* CO12 stated negative prejudices as one example: *"Very often, these discussions are only about feelings, so data helps, especially if you can compare yourself with other cities."*

Providers offer own data products and state data protection as one problem to share relevant data with other stakeholders. SP7: *"We are happy to pass on our knowledge and even have special dashboards where cities can obtain information."* SP8: *"I would say that the data protection regulation often prevents us from sharing data - it is difficult to share data or new data transfers have to be signed off."* CA1 argued that data sharing can't be generalized: *"We only want the station data or the location data of the e-scooters for the time being. We don't want to have any personal data, e.g. customer data (...), but if it relates to persons it is indeed problematic regarding data protection."*

Assimilating. Experts stated that authorities, together with providers, are making targeted adjustments, e.g. tailored operating areas. MA5: *"Are they getting to workplaces where the service area ends 200 meters from the employer? Should the service area be extended? These are things that arise during operations (...) and are then discussed and adjusted together with authorities and providers."* Further, the importance of interacting with citizens, especially non-users, has been identified by experts, e.g., MA4: *"The 95 percent of the population who don't use it should also be satisfied. The providers need to understand this target group, which is not actually their target group, much better and communicate better."* CA1: *"From the point of view of citizens, who are not so positive about it, it is extra annoying when they report an e-scooter lying in the pathway and someone only arrives a day later or even later to pick it up."*

Reforming. On the stage of reforming the dominant topic was the creation of designated parking zones, e.g. CA2: *"The main issue are e-scooters parked in an obstructive way or contrary to traffic regulations."* RE9: *"The only thing, I think, works well is to define parking zones. (...) I think that contributes to the success because it is an acceptable solution for both sides. For those who are not yet sure if they want to use it or not, it reduces the risk of not finding a vehicle."* SP7 stated the success of parking zones underpinning it with data: *"We completely turned the city center into a mandatory parking zone in a test. Nobody was allowed to park outside of fixed parking zones. (...) We didn't have fewer customers as a result, but if you walked through the city center, it looked much cleaner."* It was further suggested by experts to promote appropriate parking with monetary incentives. Interviewees pointed out that increasing citizen interaction and recognizing their needs can further improve the acceptance, e.g. when identifying parking zones. NGO11: *"What is relevant, with regard to fearful spaces and darkness and so on, is that there is social control around the parking zone. (...) A zone in the backyard is always bad, for car sharing, for an e-scooter, or a bicycle."* Citizens might suggest or rate parking zones. Integrating micromobility service providers can further increase the value and reach of such platforms, as entry barriers to micromobility services are lowered. But implementation challenges and nuanced steps towards MaaS platforms were stated. MA5: *"Cities like Munich or Berlin combine a whole range of providers, e.g. bikes, e-scooter, e-bikes, that are all searchable, bookable and can be paid for using only one app. That is, of course, the ultimate solution, which is where we want to be one day. But that's still a long way off."*

Morphing. It was pointed out that the road infrastructure is to date in an underdeveloped state which impacts traffic rule enforcement, CO12: *"A set of rules may include restrictions, no-parking zones, no-drive zones and the like. But I can make as many rules as I like, i.e. having to ride on the cycle path, if I don't have a cycle path, then it becomes difficult."* Interviewees elaborated on the strategic vision of cities and respective mobility plans, e.g. CA2: *"(...) a mobility turnaround, that people use their cars less and shared micromobility more. To get to public transport, for example, instead of driving the route in their own car. That's our goal. With fewer conflicts it could increase the overall acceptance among citizens."* Fully integrated MaaS offers should go hand in hand with public transportation services, i.e. MA5: *"We don't want to cannibalize public transport, but rather ensure that the systems strengthen each other. This is the so-called extended local public transport, and there is a lot of potential in it to encourage more and more people to move around more sustainably."*

However, the responses of experts indicate that not all the required data is assimilated yet, NGO11: *"You would first have to evaluate what benefit they have. And there would have to be really sound evidence of it. How many journeys were actually saved that might otherwise have been made by car?"* Creating offers that provide a societal net benefit is seen as crucial but data analytics capabilities and respective insights appear not mature enough, to address more potential users, RE9: *"I don't think we currently understand well enough how we can make these services so attractive that they actually reduce car journeys. So how exactly do these services have to look like, where do the vehicles have to be located, what do I have to do with private car ownership or usage to make it possible to switch to other modes of transport?"* In regard to age, CA3: *"To find out how I can address the other age groups and ask them, do you have other needs? That you don't have just one group of users who could also walk."* NGO11: *"E-mobility on bikes, for example, has an older target group. We can definitely reach them with this. So fewer e-scooters, more bicycles. You're not likely to get older people on e-scooters."* And income, RE9: *"That it penetrates other income groups. Shared bikes are relatively inexpensive, shared e-scooters are relatively expensive. With the price structure that we currently see on the market, it will hardly appeal to lower income groups. Unless it is included in public transport and you can use it to get to the bus stop."* And geographically, CA2: *"Cities could issue tenders and can state we don't just want to have the inner-city areas covered, but also the less economically attractive outer areas. However, you have to monitor or track it in some way."*

e-Governance. Real-time monitoring and enforcement of regulations is seen as an essential part of e-Governance, not only of providers but also in the context of traffic laws. Today, traffic violations are seen as a meaningful problem, e.g. CA2: *"Driving* *on sidewalks, driving in the opposite direction, cutting other people off (...) simply behaving in a way that endangers traffic."* Interviewees pointed to solutions that leverage the connectivity of shared devices. CO12: *"If they drive into the pedestrian zone, the e-scooters run out of power and users have to push. That's brilliant, it's great for enforcing laws and road traffic regulations."* Being able to respond in near real-time to sudden traffic spikes was seen as another promising scenario. SP8: *"There are considerations for live evaluations, e.g., for a soccer match, that you can predict the expected demand. But we haven't got that far yet. Theoretically, it is possible, but today we use historical data and make informed decisions based on that."*

5 Discussion, Recommendations, and Artifact Evaluation

Based on the theoretical and practical knowledge we derive our stage model, i.e. Figure 1. The citizen/service perspective shows the increasing value for citizens and growing complexity. Every stage has two objectives, the names were partly modified to incorporate the practical knowledge. After the objective to visualize *Vehicle Locations* and *Accident Locations* on a map to better understand this disruption, two maturity paths emerge for the next three stages. One aims at the acceptance of citizens while using or encountering micromobility in public. From *Tailored Operating Areas* to prevent dead ends and usage in forbidden areas, over targeted measures at *Hotspots* to counter cluttered parking and improve driver safety, to *Improving Road Infrastructure* to effectively steer investments for new road infrastructure. The other path aims at the continuous improvement of the supporting digital services platform, i.e. *Platform for Citizen Interaction*, followed by an initial *Platform for Dispersed Providers,* to *Sustainable*, *User-friendly MaaS Provision* where curated, incentivized offers allow for integrated multimodal trip chains. On the stage of e-Governance, novel approaches to problems are possible, i.e. automated *Smart Traffic Rules Enforcement* to increase traffic rules compliance and *Dynamic Provider Governance* through which micromobility providers are automatically assessed by defined indicators, based on the results automatically supported or penalized, and allowed fleet sizes adapted based on short-term demand.

The operation/technology perspective highlights the most relevant capabilities to realize the objectives. Each capability is only listed on the lowest stage it first appears. We applied identifying frames to highlight the relationship between capabilities and objectives and lines to connect capabilities that build on each other. To realize an objective on a given stage the capabilities without a frame and with the same frame as the objective must be implemented. To visualize *Vehicle Locations, Geographic Base Data* and *Historic Parking Data* are needed. On the Morphing stage, the objective *Improve Road Infrastructure*, in enabled by *Incentivize Sustainable Trips*. It describes that city authorities use their *Data Analytics Capabilities* to not only identify hotspots for *Data Driven Real World Interventions* but also expand them to a level where they can identify sustainable trips and incentivize these. This capability builds on *Billing and Accounting*, as monetary incentives can be used to incentivize sustainable trips and provided through *Sustainable, User-friendly MaaS Provision.* Similar, the interaction processes with service providers are continuously improved, from labor-intensive *Incident*

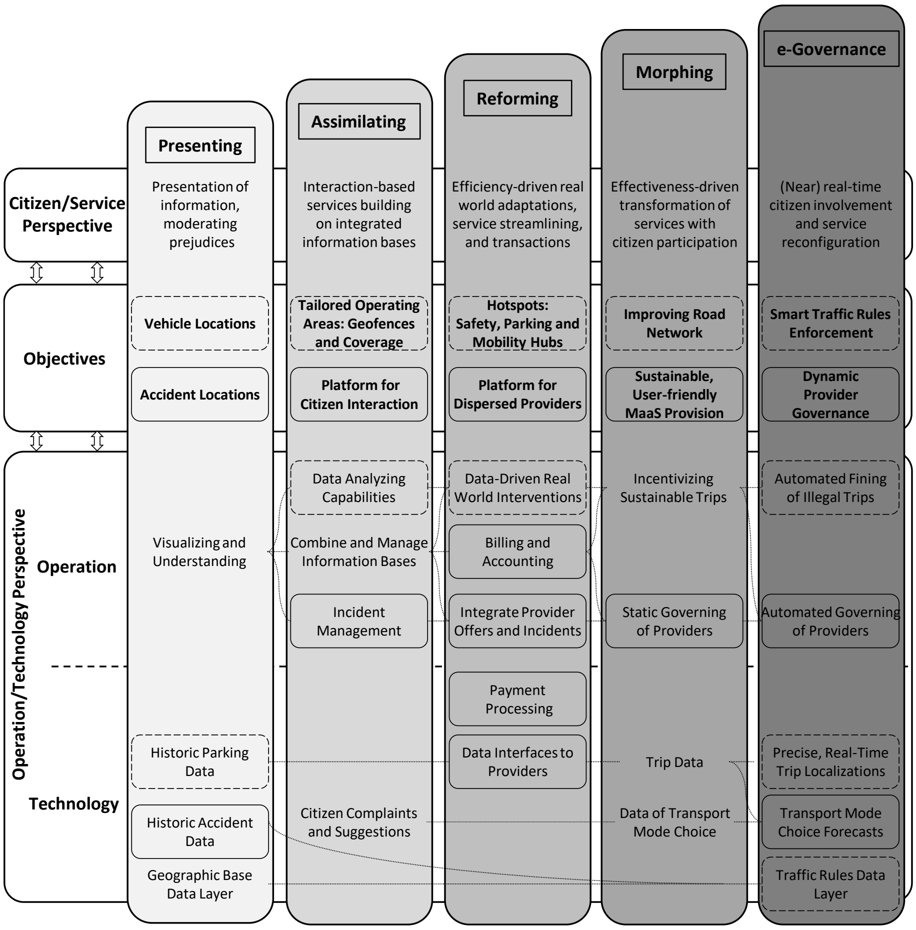

Figure 1. Stage model of data-driven micromobility governance

Management, to digitally *Integrate Provider Offers and Incidents*, *Static Governing of Providers* with penalizing schemes, and finally *Automated Governing of Providers*.

The generated value of our identified objectives can be of societal or monetary nature, e.g. through improved acceptance or more users. The implementation appears to depend on monetary incentives, governmental prioritization, regulatory frameworks and public relations work of service providers: One city was still in negotiations with providers to receive micromobility data, another one was already using dashboards, many micromobility service providers have implemented reporting interfaces for poorly parked vehicles, and software platform providers have rolled out MaaS platforms to some cities. Lee (2010) argued that the reference stage model is not normatively rigorous and progressive from a technological standpoint, as ICTs are reproducible and, building on external experience, advanced ICTs can be imported to jump stages. This raises the question how to prioritize and where to jump stages.

We find that implementation actions within cities are often a question of funding, available resources, and data. MA5: *"Very large cities can afford MaaS systems, they monitor everything with dashboards that cost a lot of money per year in order to be able to view and manage shared micromobility digitally."* CA2: *"We don't necessarily need more data. The issue for us is that we often don't have the capacities to evaluate this data in a way that we can make good use of it."* Regulations open up leverage for public authorities to outsource the realization of objectives to the private sector. We argue that cities should use their limited resources to be perceived as an equal and serious partner in resulting digital value networks, i.e. by overseeing the removal of poorly parked vehicles in an appropriate time, as highlighted in Section 4 under *Assimilating.*

Transforming personal transportation towards sustainability appears to be impeded by a lack of data. To reach higher maturity, insights must be gathered into trips that are environmentally and socially sustainable and trips that could be replaced by such. These could in turn be eligible to government subsidies. Some public transportation providers already offer non-targeted subsidies, e.g., for all short trips on shared bicycles. Cities might start time-limited interventions in underserved areas to test the acceptance and usage of different micromobility forms, to gather potential user and transport mode choice data. We see this as an essential part of data-driven *Sustainable, User-friendly MaaS Provision.* The socially sustainable provision of micromobility services for underserved groups was also examined by Sanguinetti and Alston-Stepnitz (2023) and Riggs, Kawashima and Batstone (2021) who researched regulatory policies for e-scooters in 61 cities in the United States of America. The authors recommend policies and pilot programs and emphasize that results will vary strongly based on the city size, climate, and landscape, concluding that individual analysis is needed.

Further, cities must develop transportation strategies for micromobility and objective indicators along which micromobility offers are aligned. This is supported by Sochor *et al.* (2018) who suggest quantified goals, e.g., for user attraction and emission reduction but don't elaborate on the role of service compliance measurements. While dynamic adaptation to demand can increase user numbers, little research has been conducted on the advantages of dynamic or automated provider governance for cities to reduce the need for human oversight (Li, 2019). Cities should be able to both dynamically enforce and adapt their micromobility regulatory framework based on objectives and demand. We argue that for *Dynamic Provider Governance* smart public space and curbside management will become increasingly important, to allocate space dynamically to different transportation modes. In this context near real-time processes in city authorities are required, e.g. interfaces to request larger parking zones for events or an automated expansion of parking zones following arrival spikes.

Also, the available technology and public laws can become a determining factor, i.e. for *Smart Traffic Rules Enforcement*. MA6: *"There are specific guidelines as to where e-scooters may be parked, but because the Global Positioning System (GPS) signal is not too precise, vehicles can still be parked incorrectly."* Bäßmann *et al.* (2023) suggest to use 5G networks to improve the localization accuracy. Also, tenders could require precise, certified GPS hardware in vehicles. To date, fining traffic offenders may not be legally possible through digital tracking and with different types of data varying data protection rules apply. We recommend that stakeholders identify how data regulations can be implemented and that authorities advocate for digital law enforcement.

Lastly, Schumann, Haitao, and Quddus (2023) identify a lack of accident research that was also criticized by MA5: *"That well documented studies are finally launched that put the accident figures in relation to the passenger kilometers traveled, that this information finally becomes facts."* The authors as well suggested that authorities use big data to identify accident-prone areas and preventive measures like speed throttling.

The mentioned aspects can cause a non-linear maturity path in our stage model. The conflict of multiple and possibly equifinal existing maturity paths is a common criticism (Röglinger, Pöppelbuß and Becker, 2012). To mitigate this, the authors suggest design science, that we applied. Our resulting stage model is designed to provide a set of objectives and prerequisites that can be executed independently but profit from linear implementation for the two paths, i.e. acceptance improvement and digital platform improvement. Considering the import of external ICTs, Lee (2010) argued that from a citizen/service perspective jumping stages in processes and services in the real world is harder and can potentially cause resistance to change. Therefore, implementing objectives and operations from lower stages can pay dividend for organizations by reducing aversion, even though, technologically, jumping stages might appear attractive.

6 Limitations, Conclusions, and Further Research

Our stage model is still limited. Another evaluation round with experts and consecutive improvement can increase the validity of the model. Our practical knowledge originates from experts focusing on large urban agglomerations in Germany and Austria. Thus, results and objectives may vary for other regions and rural areas. For further research, extended interviews for the evaluation and the geographic scope are important.

We contribute to theory our findings on how cities can successively implement data-driven micromobility objectives to continuously improve the quality of life of citizens and reduce aversion. We found that the existing literature has focused much on the operational/technology perspective and less on acceptance from the citizen/service perspective. We add to the latter perspective through our expert interviews. For this we extended and adapted the reference stage model proposed by Lee (2010). For practitioners, we identify as one aspect to further increase the collaboration between cities and service providers, e.g., by designing joint communication and action plans to improve the acceptance and success among the general population. Further, there is a lack of research on detailed accident studies for e-scooters, transport mode choice data and automated service governance from which targeted interventions could be derived. This will help cities to implement sustainable transportation plans. The lack of resources for data analytics in public authorities can be addressed with research projects that provide open source toolboxes on low code or no code basis.

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