The Hitchhiker's Guide to Urban Spaces

Conceptualizing a Gaia-X-enabled Co-bility Hub Combining Public Transport, Crowd Mobility, and Last Mile Logistics

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Abstract: Urban transportation is increasingly challenged by growing populations and the rapid growth of e-commerce, thus, driving data-driven innovations for sustainable mobility services. Shared mobility consequently emerges as a promising city transport concept, while combined service opportunities between public transport, crowd mobility, and last mile logistics are scarcely investigated. In this paper, we explore the co-creation of urban mobility services within federated ecosystems focusing on a transshipment hub, and propose a novel approach called "co-bility." Following a design science research (DSR) approach, we conceptualize a co-bility hub based on literature and expert interviews with practitioners from the mobility sector. The exchange of data and services in urban spaces is based on the technical framework Gaia-X. Our study findings show that a Gaia-X-enabled co-bility hub can be achieved by (a) a federated ecosystem orchestrating mobility services and resources, (b) municipalities ensuring coherent platform governance, and (c) eclectic incentives to make co-bility successful.

Keywords: Shared Mobility Hub, Co-bility, Public Transportation, Crowd Mobility, Last Mile Logistics, Gaia-X, Design Science Research

1 Introduction

In 2018, about 55% of the world's population lives in cities with estimates of 68% to be reached by 2050 [Un19] resulting in higher volumes of passenger transport. At the same time, worldwide retail e-commerce sales are expected to increase by 23.6% between 2020 and 2025 with a forecasted sales record of approximately $7.4 trillion [In23], driving a continuously growing "last mile" delivery market [As20]. Although urban transport activities relying on motor vehicles account for substantial amounts of emissions generated, sustainable mobility solutions through technological advancements (e.g., electric vehicles) are yet facing challenges. Furthermore, the pertinent problems from the transportation of passengers and goods in cities are related to severe environmental effects (e.g., traffic congestion) [Eu06]. To address these issues, the

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promising concept of shared mobility and transport collaboration in urban areas has leveraged new forms of platform-enabled mobility services [Cl19]. For instance, platform providers have recognized shared service capabilities for crowd mobility comprising cars, bikes, and e-scooters facilitating *mobility as a service* (MaaS) business [AG20] or *mobility on demand* concepts [SC20]. Likewise, last mile delivery innovations have demonstrated benefits for achieving automated deliveries by remotely operating driverless drones or robots for the courier, express, and parcel (CEP) providers [As20]. At the same time, commercial road freight transportation is increasingly turned into a data-driven platform business [He22].

In recent years, the integration of passenger, crowds, and freight transport has shaped multifold concepts (e.g., crowdsourcing, co-modality, cargo hitching) [CN22, Ho06] and revealed the idea of a "shared mobility hub" [Ro23] aiming at sustainable urban mobility ecosystems. Nevertheless, public and crowd resources used to support CEP providers in delivering shipments are accompanied by organizational and technological challenges of collaboration [Cl19]. However, shared or collaborative mobility remains an isolated phenomenon and lacks a comprehensive view to combine public transport, crowd mobility, and last mile deliveries [SR19], requiring design knowledge to strengthen the development of co-created mobility services for collaborative innovations [SC16]. In this context, the transformation of urban transportation by platform innovations across different research fields [Ce21] motivates the exploration of interconnected mobility systems using emerging federated ecosystems (e.g., Gaia-X) to maintain digital sovereignty and to secure data exchange between the actors involved [Br21, He23]. For this reason, this paper explores the co-creation of mobility services by combining public transportation, crowd mobility, and last mile logistics framed by the novel approach "co-bility" based on a federated architecture. The idea of a co-bility hub arises from a current Gaia-X research project focusing on competitive fleet management in urban areas and combining transport resources from the public (e.g., buses) and last mile delivery operations (e.g., delivery robots). Since value propositions found in higher transport capacities utilization, synchronizing pick-up and drop-off (PUDO) service levels, and socializing opportunities [CN22, Du19] arrive, the research question (RQ) guiding this study to establish a concept for both practice and future research is as follows: *How can a co-bility hub combining public transport, crowd mobility, and last mile logistics in urban areas be conceptualized based on the ecosystem Gaia-X?*

To answer the RQ, the remainder of the paper is divided into seven sections. In Section 2, we provide the fundamentals of our study comprising shared mobility hubs, the co-bility hub approach, and the federated ecosystem Gaia-X. Subsequently, in Section 3, we establish a design science research (DSR) approach comprising a theoretical knowledge base and identified business needs from expert interviews of the current Gaia-X project research community. Afterward, we present the concept of a co-bility hub and describe a Gaia-X-enabled platform for sovereign data exchange (Section 4). Then, in Section 5, we evaluate the derived concept through an architecture analysis. In Section 6, we discuss the finding for academia and practice and draw the limitations. Finally, we conclude with an outlook for future research in Section 7.

2 Foundations

2.1 Emergence of shared mobility hubs in urban areas

Shared mobility hubs represent novel innovations in the field of mobility [Bl22] and emerge growingly by combining different transport modes to foster sustainable mobility in cities [Ro23]. The key value propositions of these hubs are found in the substitution of privately owned assets, vehicle utilization, and social interactions by contributing actors [Co21]. As mobility options, shared cargo bikes, e-scooters, and cars in combination with public transport systems are integrated at a dedicated place [Ro23]. For example, in the Dutch city of Amsterdam, a shared mobility hub was inaugurated in 2021 next to a hotel and within 100m distance of a metro station offering shared e-bikes, e-cars, and cargo bikes [Ro23]. Considering the dramatic change in energy and resource efficiency, the increasing number of related EU-funded projects (e.g., SmartHubs [Sm23] and eHUBS [NW23]) indicate the substantial relevance of future shared mobility hubs for cities [Ro23]. Overall, there are different aspects to be considered for setting up a shared mobility hub at a certain location, such as the expected earnings for the operator, the investment and operating costs, the additional space needed, the generalized travel costs of using the hub by the end-user, the increase in travel time reliability for the end-user, and the impact on quality of life and emissions [Bl22].

2.2 Co-bility hub: Approach and definition

Due to the recent shared mobility trends based on vehicles or passenger rides [SC20], future mobility ecosystems will rely increasingly on advanced connectivity between urban transport modes [SC16]. Shared mobility hubs are, thus, recognized as places, "*where different transport modes are integrated seamlessly, promoting efficient and sustainable urban mobility*." [Ro23, p. 6]. The hubs are associated with cargo bikes or amenities like stationary PUDO points, making them a place for integrating last mile delivery activities. To integrate mobility resources and provide mobility services to ecosystem participants, digital platforms provide flexible cloud infrastructure. Digital mobility platforms, therefore, emerge as marketplaces [SR19] and are associated with multi-sided markets [HW15] allowing the exploration of value co-creation opportunities [Va08] discussed in the mobility context [Sc23]. In reflecting on the integration of mobility resources and the provision of connected mobility services to be exchanged between ecosystem actors for mutual benefit, we introduce the term "co-bility," a portmanteau comprising "co-creation" and "mobility." Following the proposed definition of shared mobility hubs [Ro23], a co-bility hub consequently describes a place in urban areas where passengers, crowds, and freight are integrated into a platform to facilitate seamless collaboration for mutual benefit by promoting data and service exchange between mobility providers and consumers. Capturing value within a co-bility hub, thus, follows different propositions (e.g., co-creation) formed by platform interactions between participants entailing collaborations [Va17].

2.3 Shared mobility in the federated ecosystem Gaia-X

The Gaia-X initiative has been launched primarily by Germany and France in 2019 to provide a (technical) framework offering the European economy a competitive alternative to the dominance of “hyperscalers” in the cloud business [BM19]. Gaia-X consequently aims at providing companies with a trustworthy and decentralized data ecosystem based on a federated data infrastructure. It is expected that Gaia-X will support interoperable data exchange, thus, enabling collaborative value creation and joint business models [Kr23]. However, Gaia-X Federation Services (GXFS) represent the enabling software components currently maturing by ongoing implementations of open-source software [As23]. In this light, shared mobility offers a fruitful research avenue for the Gaia-X development currently addressed, for instance, by current projects focussing on transport automation and data interoperability between freight fleets [He23]. Based on the Gaia-X principles, the Mobility Data Space[3] has been launched in 2020 to exchange mobility data [Ot22]. The value propositions of the data space follow the idea of a platform-enabled marketplace where data is offered or purchased by participants (e.g., service providers) accessing the network. Likewise, the data consumed by searching a data catalog allows for creating new services provided by the ecosystem participants [Ot22]. Since the scope of implemented business services based on the architecture has shown benefits to the actors by provisioning information [Mo23], further collaboration opportunities arrive by combining public transport, crowd mobility, and last mile logistics and favor the exploration of a Gaia-X-enabled co-bility hub.

3 Research Method

To answer the guiding RQ in this paper, our study follows the DSR principles to analyze knowledge from both science and practice for the creation of a co-bility hub [He04]. For the entry point of our study, literature from academia was used to ground a scientific knowledge base (rigor). Relevant stakeholders and collaboration approaches related to a platform-enabled co-bility hub were primarily identified in the work of [Cl19] and [SR19]. Subsequently, knowledge from practice was gained from expert interviews and document-based analysis to identify business needs (relevance) responding to the practical character of our topic. To evaluate the derived concept, an architecture analysis [He04] was performed to assess the fit with the developing Gaia-X components resulting from the ongoing research project GAIA-X 4 ROMS. The research framework covered in this paper follows the DSR guidelines outlined by [He04]. Overall, the goal is to build a novel design artifact that extends the current knowledge base and respects its applicability in business environments as detailed in Figure 1.

[3] https://mobility-dataspace.eu, accessed: 14/04/2023.

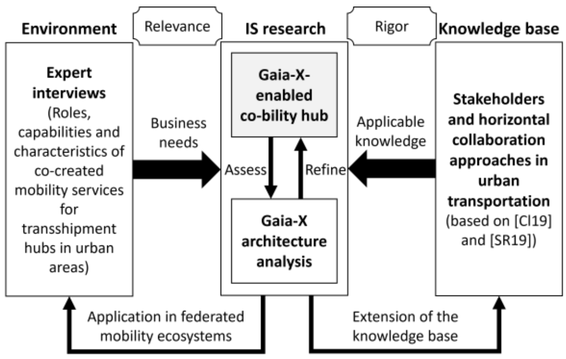

Fig. 1: Research framework for the co-bility hub adapted from [He04]

To gather insights from practice, semi-structured interviews [He04] were conducted with experts involved in the mentioned Gaia-X research project. The research project is part of the project family GAIA-X 4 FUTURE MOBILITY[4], and the participating organizations forming individual consortiums provide access to potential experts related to the topic of our research study. In Figure 2, an anonymized overview of the 12 interviewed experts including the organization role, organization size (per EU definition), position, work experience, and interview duration is provided.

Org. type	Org. size	Expert position	Experience	Duration
Last mile logistics software provider A	Large	AI solution architect and data spaces	12 yrs	40 min
Last mile logistics software provider B	Large	Last mile logistics innovations manager	4 yrs	44 min
Last mile logistics software provider C	Large	Business developer smart city	5 yrs	46 min
Mobility software provider A	Medium	Sales manager mobility sol.	25 yrs	50 min
Mobility software provider B	Small	Innovation/network manager	10 yrs	50 min
Mobility software provider C	Small	Project manager mobility data spaces	3 yrs	54 min
Mobility software provider D	Small	Senior project manager intelligent mobility	4 yrs	56 min
Municipality of a city	Large	Consulter urban mobility and federated data spaces	15 yrs	49 min
Public transport provider A	Large	Technical consultant mobility	1 yrs	43 min
Public transport provider B	Large	Product owner digital mobil.	2 yrs	44 min
Research institution A	Large	Researcher for intelligent/ connected mobility systems	2 yrs	34 min
Research institution B	Medium	Professorship for mobility, retail, and logistics	23 yrs	45 min

Fig. 2: Overview of interviewed experts

[4] https://www.gaia-x4futuremobility.dlr.de/, accessed: 10/05/2023.

An interview guide was sent to the experts beforehand consisting of open questions divided into five parts: (1) introduction, (2) combined mobility, (3) Gaia-X enabled co-creation opportunities, (4) co-bility hub requirements, and (5) challenges and risks. To analyze the collected data, the interviews were coded following deductive and inductive category formation [Ma14]. The interviews were extended with elements for constructing, justifying, and conflicts of interactions for interpretative research [Wa06], and we asked follow-up questions to gain more in-depth information on specific topics (e.g., business models). This strategy allows enriching information for the topic addressed by our research study, which results from discussions with the respondents [Pa15]. To arrive at the desired artifact of a Gaia-X-enabled co-bility hub, the method of conceptual modeling [ET11] was applied to describe the platform application on an abstracted level composed of resources, infrastructure, services, and participants. From the findings of our analysis, we extend the knowledge base in the field of mobility ecosystems and obtain a model that contributes to nascent design theory positioned within the framework of DSR contribution types [GH13]. The intended artifact, thus, represents an exaptation in the DSR knowledge contribution framework [GH13], implying the extension of known solutions to new phenomena and fields of applications (i.e., co-created mobility combing passengers, crowd, and freight transportation).

4 Conceptualization of a Gaia-X-enabled Co-bility Hub

4.1 Design elicitation of a Gaia-X-enabled co-bility hub

Following the work of [SR19], a Gaia-X-enabled co-bility hub grounds on six stakeholder groups directly interacting with each other: (1) MaaS provider (e.g., car sharing provider), (2) CEP delivery provider (e.g., logistics company), (3) craftsman (e.g., construction companies for private persons), (4) crowd (e.g., private person, individual), (5) public transport service provider (e.g., fleet operator of buses), and (6) retailer (e.g., grocery store, entrepreneur). Although additional stakeholders with relevance to the infrastructure of a co-bility hub were mentioned (e.g., provider of electricity stations) during the interviews, no direct linkage was recognized for co-creating platform services. From the expert interviews, we consolidated the requirements and identified transactions between the participants that are manifested by four core services: (a) last mile delivery support (e.g., individuals take parcels from CEP after route matching), (b) retail shopping forwarding (e.g., entrepreneurs offer purchases for delivery to individuals), (c) material supply storing (e.g., craftsman can book dedicated parking zone to ensure supply during constructions), and (d) crowd mobility matchmaking (e.g., individuals share assets or make use of transport rates collaboratively). To realize these services, the interview participants emphasized that transport capacities and vehicle resources require integrating them into the hub system. Furthermore, we noticed a consensus from the experts on the role of the municipality, to be positioned as a platform provider (e.g., server host) to govern secure and reliable transactions based on GXFS components. In this light, all experts from our interviews have acknowledged the capabilities of Gaia-X to be applied as the technical framework providing federated data exchange components for the participants (e.g., onboarding, logging, identity management, service catalog). However, fundamental requirements to make value co-creation for shared mobility services successful rely on incentive mechanisms and were stressed by all experts. Therefore, incentives are pivotal to building acceptance and making the platform solution attractive [Cl19], thus, encouraging participants to realize network effects. During our discussions, we have identified versatile incentive opportunities encompassing credit points (e.g., parcels being forwarded are awarded credits for individual benefits), gamification (e.g., hub performance is set as a competition between participants), repayments or discounts (e.g., cost saving of CEP provider are shared with individuals), social interactions (e.g., individuals meet-up for vehicle sharing supporting socializing), and service level improvements (e.g., retailers involve the crow to deliver purchases to elderly people). Overall, the engaged participants in the co-bility hub appear to follow their personal benefits or business model opportunities likewise to be governed by the municipality.

4.2 Conceptual model of a Gaia-X-enabled co-bility hub

The elicited findings described above form the basis for a co-bility hub focalizing the co-creation of mobility services based on a federated data infrastructure. From the identified stakeholders, co-created services, integrated resources, and incentive opportunities, we constitute a conceptual model and arrive at a generic Gaia-X-enabled co-bility hub combining public transport, crowd mobility, and last mile logistics (Figure 3).

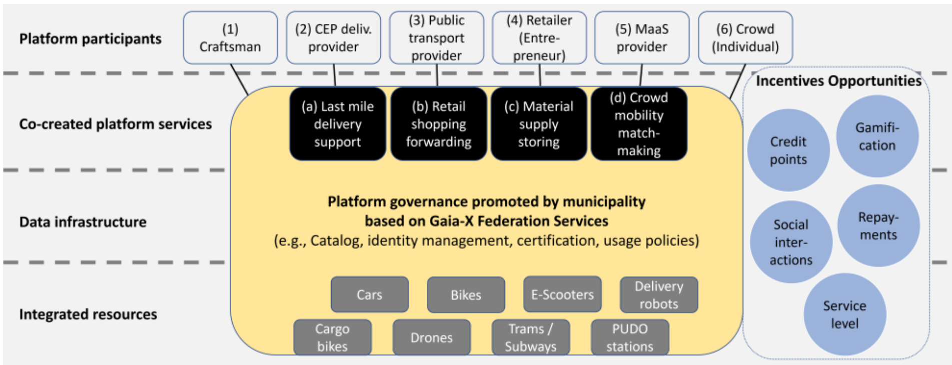

Fig. 3: Generic concept of the Gaia-X-enabled co-bility hub

Within the proposed concept of a co-bility hub, platform interactions remain abstracted according to our findings and miss further information to detail the requirements and functions on a more granular level. Therefore, the provided conceptual model is a first-time approach for grasping co-bility that makes an urban interconnected mobility system associated with emerging federated ecosystems (i.e., Gaia-X) applicable in practice.

5 Evaluation by Gaia-X Architecture Analysis

To evaluate the proposed Gaia-X-enabled co-bility hub, an architecture analysis was performed based on publicly available information from the Gaia-X database and scientific papers addressing federated data infrastructures. The authors focussed on knowledge related to data-driven services offerings in the context of mobility and demonstrations that could serve as a basis to position the derived concept. Subsequently, from the results of our analysis, an abstracted data space architecture was derived for the conceptualized model and further collated with the artifacts from the ongoing research project GAIA-X 4 ROMS. From that basis, the authors present the corresponding federation services and components to obtain a federated data space aligned with the general concept of the nascent Gaia-X ecosystem. As a result, the created co-bility hub data space represents a multi-stakeholder environment and follows the federated data infrastructure implemented for the Mobility Data Space. The participants are connected using a connector (e.g., Eclipse Data Space Connector [Ec23] for providing and consuming data encapsulated in co-created mobility services. A federated catalog allows both data providers and consumers to describe their offerings or search for the desired data or services. Accessing the data or the service is only possible by the data owner's self-determination, enabling data sovereignty. In addition, the catalog is open to other providers (e.g., software developers) and consumers (e.g., vehicle manufacturers) from other domains supporting the interoperability of the data space (Figure 4).

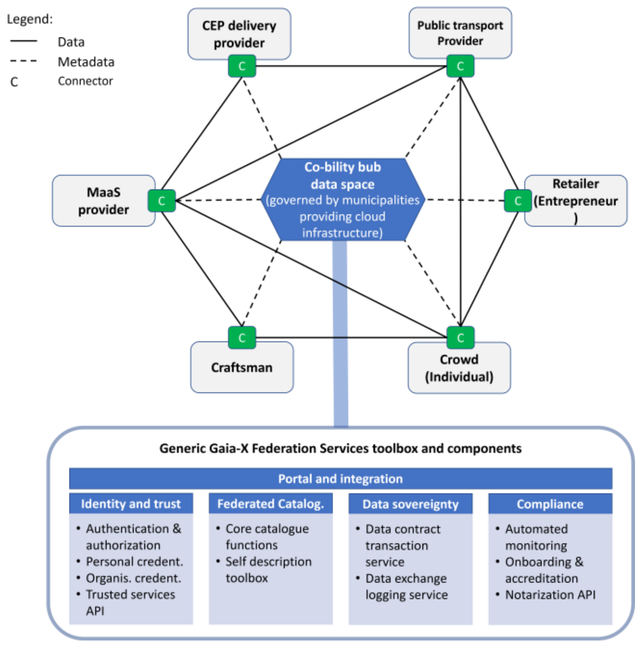

Fig. 4: Overview of the co-bility hub data space derived from analysis and adapted from [Ot22]

Notwithstanding these provisions, data from resources (e.g., PUDO stations, vehicles) use technologies (e.g., Internet of Things) facilitating co-created platform services to be integrated via connectors with other back-end components. Overall, municipalities could govern the service-oriented transactions restricted to the cloud infrastructure and incentive settings. It may comprise the authentication of the participants, the notarization of data and services offered, and the regulations on compensations. A general overview of the generic co-bility hub data space is finally built based on the generic Gaia-X Federation Services toolbox and components provided by the eco – Verband der Internetwirtschaft e.V.[5] discussed in the context of the research project GAIA-X 4 ROMS. In essence, the authors reflected several benefits during the analysis capturing value through co-created mobility services within a secure and federated data infrastructure. This includes (1) the sovereign service provisioning and consuming, (2) the integration of isolated urban mobility stakeholders, (3) the incentive opportunities for social engagement of the crowd, (4) the business opportunities for commercial transport providers, and (5) the data exchange in compliance with European legislation.

6 Discussion and Limitations

The concept derived from our DSR analysis represents a platform-enabled artifact aiming at sustainable mobility and mitigating traffic impact in urban areas. To this end, co-created mobility services entail value propositions focusing on delivery support of parcels, take away retailer purchases, storing of material supply for urban constructions, and matchmaking opportunities of the crowd mobility offerings. We answer our research question with a designed solution called co-bility hub established by a transshipment point for commodities and co-created services between platform participants. Co-bility is, thus, positioned at the edge of smart cities and smart mobility through digital innovations and collaborative transportation within urban spaces. Our proposed conceptual model responds to the rise of interconnected urban transportation in the sharing economy [SC20] and provides a federated approach that goes beyond collaborative city logistics systems [Cl19] based on the domain-transferable GXFS components. In addition, the identified provider role of municipalities addressing platform governance corresponds with the findings from [Sc23] and confirms the orchestration of transactions from outside the mobility operations. However, the target of this study was not to understand the service capabilities of existing mobility solutions operated in cities. Rather, our DSR study focuses on the design of a mobility hub for passenger, crowd, and freight incorporating shared service opportunities [Ro23], associated with the Gaia-X framework to achieve an interoperable and sovereign urban ecosystem. The presented co-bility hub provides theoretical design knowledge with valuable insights, likewise relevant for practice. The conceptualized model can be seen as a reference to guide stakeholders to achieve collaborative transport in cities. While the acceptance remains critical to realize a co-bility hub [Cl19], the concept provides new

[5] https://www.eco.de/, accessed: 10/05/2023.

impetus to make urban spaces a data-driven business field and may attract additional stakeholders such as fleet operators or insurance companies.

Although our DSR study is based on a careful selection of interview participants and rigorous data analysis, our findings are neither complete nor comprehensive. Other experts from the mobility domain and apart from the Gaia-X research community would have identified other stakeholders and service potentials. Due to the novelty of the topic, co-created mobility services derived from the interviews have resulted in the abstraction of service specifications for the concept, thus, entailing an uncertainty to meet all functions required. Not to be forgotten are the challenging aspects related to the concept and discussed with the experts. It comprises the segregation of liability (e.g., loss or damage, of parcel deliveries), planning dimensions for matchmaking resources, business model requirements, tracking capabilities, and usability propositions including the personalization for special groups (e.g., disabled individuals). Our work can only be seen as a starting point and calls for more profound knowledge to make co-bility a sustainable transport service, for instance, by considering emerging "eco-labelling" concepts [Ke22].

7 Conclusion and Outlook

The demand for future urban transport is expected to rapidly grow with severe consequences for the traffic infrastructure and the environment. In this light, our research study contributes to sustainable transportation by exploring platform-enabled co-creation between public transport, crowd mobility, and last mile logistics. Following a DSR approach [He04], we used existing literature and conducted interviews with 12 experts from the digital mobility sector to derive a platform-enabled shared mobility hub. The concept strengthens the co-created mobility in urban ecosystems by combining transport resources from different areas resulting in transaction-based services comprising capacity utilization, advanced service levels, and social interactions termed co-bility as a novel approach. The designed artifact was evaluated by performing an architecture analysis aligned to the Gaia-X ecosystem yielding mutual benefits between platform participants. Whether the presented concept will succeed in the real world by implementing demonstrations addressing the identified services using the Gaia-X framework may result in new questions driving future research activities. We hope that our work will help to span the gap between theory and practice and augment design knowledge with high societal and ecological relevance in the sphere of urban spaces.

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