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Mobility Data Space – First Implementation and Business Opportunities

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Abstract

Data spaces are open and decentral ecosystems, which ensure a trustworthy, safe and secure data exchange. Within the mobility sector, trusted data exchange and processing are emerging as key enablers of digitalization and new mobility offerings. Improved services and new business opportunities, such as more seamless travel with intermodal solutions, for example, require a willingness of stakeholders to share data, which, in turn, depends on harmonized and commonly accepted solutions to govern such data exchange. Fortunately, a first implementation, the Mobility Data Space, is untying this knot by adopting data space concepts from the International Data Spaces Association. Core components complement the decentral concept and foster discoverability, accessibility, interoperability, and trustworthiness. In a German project, a minimal viable demonstrator has been implemented, which includes core components, various data sources and first applications. It proves the feasibility of the data space concepts for the mobility sector and paves the way for its business evolution.

Keywords: New Business Models, Data Sovereignty.

1. Introduction

The mobility sector is a heterogeneous ecosystem with numerous diverse stakeholders pursuing often similar objectives, but from different perspectives and with different approaches. Exchange of mobility data between the various stakeholders – travelers, mobility service providers, infrastructure providers and many more – is a key enabler for enhanced and new mobility services aiming for safe, efficient and seamless mobility.

The aim and need to build a trustworthy ecosystem for safe and secure data exchange is not unique for the mobility sector. The European Commission has identified this challenge in the Data Strategy and proposed to establish a single market for data in the EU [1]. For 9 key sectors, dedicated European Data

Spaces are envisaged, one of them being mobility. According to this vision, in such a data space, »personal as well as non-personal data, including sensitive business data, are secure and businesses also have easy access to an almost infinite amount of high-quality industrial data«. This means that data providers can trust that their data assets will be transferred to and used by third parties only in a prescribed manner and according to well-defined conditions.

In 2018, we presented the endeavor to apply the data space concepts of the International Data Spaces Association (IDSA) [2, 3] also for the mobility sector [4]. The Delegated Regulations under the ITS Directive mandate the provision of various types of mobility data as well as the creation of National Access Points (NAPs) in the Member States [5]. The Mobility Data Space (MobiDS) targets not only compliance with the minimum legal provisions, but to embed the NAPs and the data provision mechanisms into a comprehensive ecosystem for mobility data. Mobility data is made available to a broader user group while ensuring full data sovereignty to the data provider. This supports the above-mentioned spirit of the Data Strategy and also fits to the action plan of the Smart and Sustainable Mobility Strategy of the European Commission [6].

In 2019, the project Mobility Data Space started with a consortium of 11 partners from Germany to demonstrate the implementation of data space concepts with two use cases [7]. While the basic ideas were published in a Whitepaper [8], the first minimal viable demonstrator (MVD) was realized.

Participants of a data space exchange data through a data space connector which ensures secure data exchange and processing in a controlled decentralized environment – the secured data space. However, the data space concepts additionally allow central components which foster discoverability, accessibility and trustworthiness. As these characteristics are of great significance for the MobiDS, the demonstrator provides a metadata directory - also called metadata broker. Where available, the work of IDSA on components like the connectors and the metadata broker as well as the work on the IDS Information Model [9] as the domain-agnostic, common language are used as a fundament and developed further to MobiDS components. In consecutive versions of the MVD, more central components will finally enable a data space with full capabilities also allowing exchange of data with attached usage policies in a data space with usage control securing data at rest, in use and in motion.

This paper first describes the general concepts and capabilities of the IDSA with a strong focus on the aspects of particular concern for the mobility sector like central components in data platforms (section 2). After that, the major issues of the implementation of these concepts are summarized which includes the description of two types of connectors and the metadata broker (section 3). Section 4 sets the MobiDS endeavor in context to related initiatives which strive for wider application and upscaling of MobiDS concepts realizing and enabling new business opportunities before section 5 concludes with an outlook.

2. MobiDS Concepts & Capabilities

Data Sovereignty through Usage Control in isolated and controlled Data Apps

Participation in a secure data space is possible via a technical connector component that data providers and data users either host themselves or have hosted for them, cf. Figure 1. The data space is established across the networked connectors, meaning that it is not a centralized platform but rather an expandable

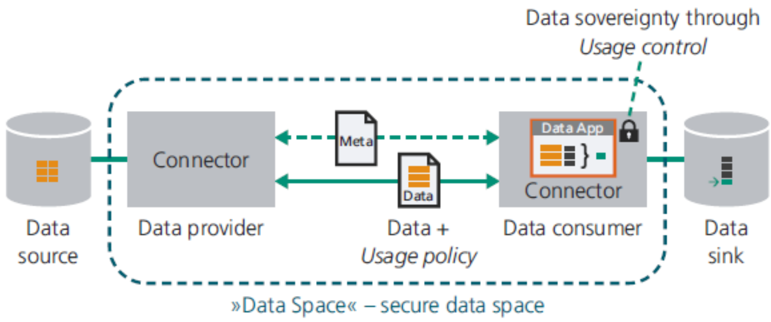

Figure 1 – Functional principle of data sovereignty through mechanisms for data usage control

network of decentralized players (minimum of two). Before being transferred to the target connector, the data to be provided is extended by a set of rules, the so-called »usage policy«. The data remains in the target connector and is secure against direct access by the data user. If data users want to work with the data, e.g., for purposes of data analysis or fusion, they must access it within the connector via so-called »data apps«.

These apps are capable of integrating further data, e.g., from user databases that are run outside of the connector. A usage control layer within the connector guarantees compliance of the data app with the specified rules, with the effect that only aggregated results will leave the connector. All steps taken during data use and processing within the data space can be recorded. This way, data providers have complete knowledge of all activities relating to their data.

Central Components in the Mobility Data Space

Beyond the minimum example, a data space can consist of dozens or even hundreds of participants. This kind of decentralized, distributed system requires a central directory in which data sources and services are published and which can be searched either manually or automatically by data users. Therefore, existing regional and national mobility data platforms play a special part within the Mobility Data Space. With different operator and business models, one or more central components for the data space can be offered, cf. Figure 2:

- A **data marketplace** (technically, a metadata directory), for the publication and displaying of data sources and their terms of use. Metadata needs to be provided in a machine-readable format so that devices such as automated vehicles, smartphones and IoT devices will be able to find and use them autonomously.
- A **vocabulary provider** that provides the necessary domain knowledge about traffic and mobility data formats (e. g., DATEX II, NeTEx) as well as APIs (e. g., SIRI, TRIAS) in the form of vocabularies and ontologies, thus ensuring the machine-readability and interoperability of data.
- An **identity provider** as a single point of contact that evaluates the trustworthiness of data providers, data users as well as data and data apps, and that also allows secure communication based on the aforementioned evaluations.
- A **data app store** for the easy registering and marketing of data apps (for the processing of data relating to mobility).

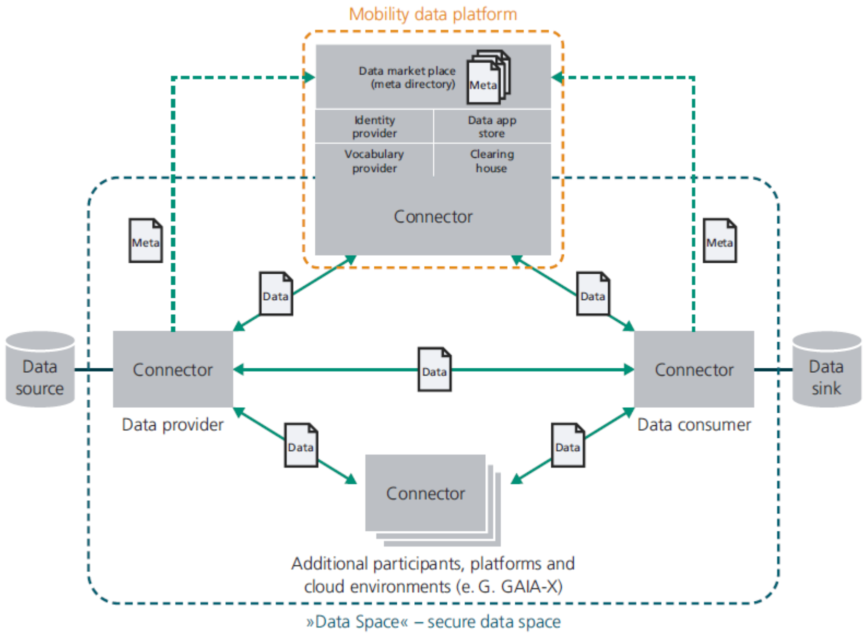

Figure 2 – A data platform in the Mobility Data Space extended by IDS components

- A **clearing house**, the system's central logging component, that records transactions made within the distributed system in order to make them available to the relevant parties for purposes of billing and quality analysis at a later point in time.

The connector also allows the exchange of data between data providers and users via the platform. This facilitates the brokering of data through which data users can subscribe to data publications and receive the data provided by the respective data providers in real time. In addition to this brokering task, the connector can execute data apps, for example, to compile the data provided to the platform into new virtual data sources. This way, existing data platforms can be extended to receive sensitive data worth protecting as well as mobility data from data providers and other data platforms, and to transfer them in compliance with the usage policy to data apps for enhancement and exploitation.

Contracts and Modelling Capabilities

Required for the exchange of usage policies is an initial agreement of data providers and consumers about the contents of these policies, a set of possibly interlinked permissions, duties and obligations. Before any data exchange, connectors fulfill at least a handshake over so-called IDS Contracts. Despite the final handshake and agreement, connectors and their curators may take part in a negotiation sequence defining fine-grained details of the contracts. Required parts of these contracts will afterwards be transformed to the actual usage control objects attached to the data, allowing data owners to define usage rights individually for each consumer. Basis for this procedure is a shared understanding of IDS Contracts, by machines and also humans. This is achieved by representing any IDS Metadata, including contracts, as a Resource Description Framework (RDF). Defined by the IDS Policy Language [10], extending the Open Digital Rights Language [11], the vocabulary and structure of the usage contracts is described in the IDS Information Model [12]. A contract comprises a set of permissions, duties and obligations, which are all considered as rules. These rules define assigners, assignees, actions, constraints and can relate to other rules. As the capabilities of this modelling approach enable arbitrary complex contracts, an IDS Connector is forced to communicate which language constructs it can process and which policies it can enforce, in its self-description.

Data Representation and Data Marketplace

The data marketplace should provide a central service for the publishing and searching of data, with interfaces for humans and machines. As contracts and metadata are already defined in terms of RDF, also the metadata broker is supporting this data representation. Although users still need to provide certain key information, like identity credentials and mandatory metadata, the broker can persistently store any metadata that complies with RDF standards. This enables data owners to describe their data as individually as they require it, and services and consumers to query for the metadata they need. This means also that no central institution is required to specify all supported metadata tags. Data sets can be directly linked by their common metadata, if curators reuse existing vocabularies. This procedure is not only applicable for the metadata of resources but also to connectors themselves, offering the possibility of reference and publish endpoints (SIRI, TRIAS), interfaces (REST, SFTP), even used protocols and data schemes (DATEX II, NeTEx) at the metadata broker.

3. First implementation – the Minimal Viable Demonstrator

The first Minimal Viable Demonstrator (MVD) of the project provides a running infrastructure to achieve a starting point for the implementation of use cases. The primary target is to establish trusted data exchange within the Mobility Data Space. To achieve better automation and usability, we will add components to complete the infrastructure in the following phases of the project. In the beginning, the

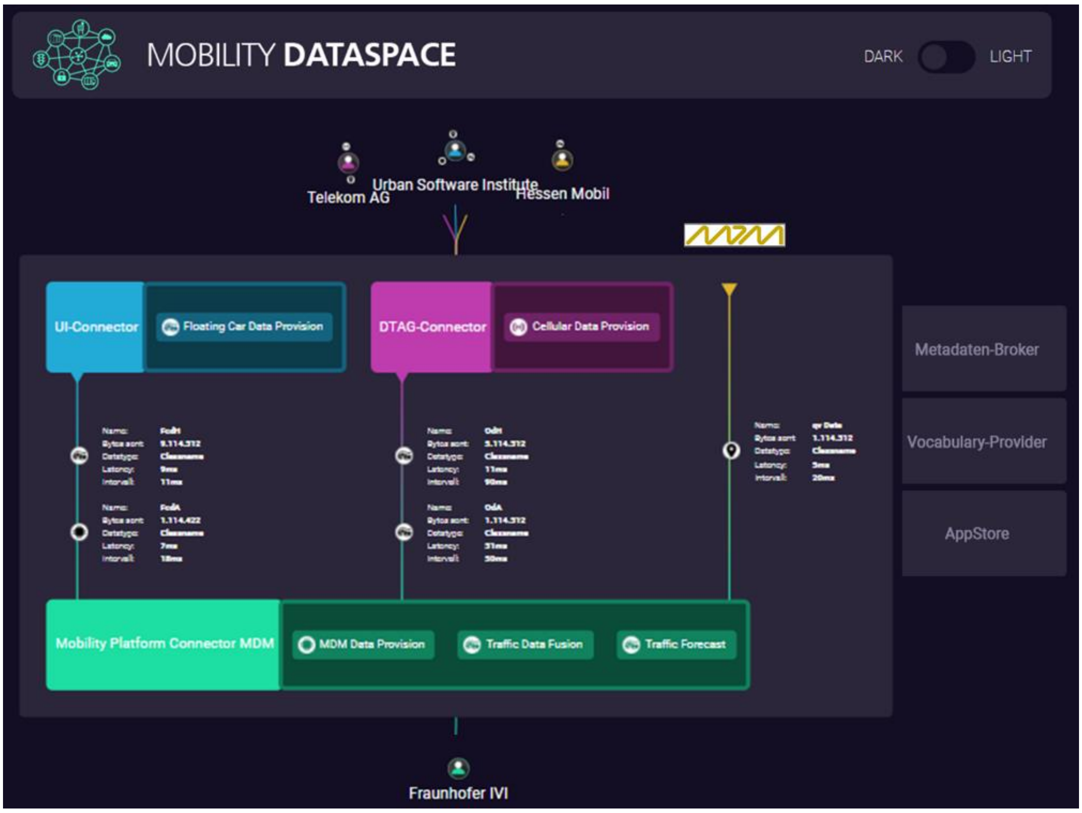

Figure 3 – Clearing House dashboard showing the status of connections between the connectors

minimal setup comprises three connectors and a metadata broker. We intended to implement two of the connectors for the provision of commercial data and one connector for providing an interface to the Mobility Data Marketplace (MDM) [13], hosting multiple connected data apps for data integration. All data offered within the MVD is publicly discoverable in the metadata broker. In addition, we implemented the first version of a clearing house, that can be optionally used to log and protocol interactions within the Mobility Data Space. Figure 3 depicts the data providers with their connectors (top), the data consumer with its connector (bottom), as well as the central services (right).

Connectors

Decentralization in a data space is a multi-dimensional process. In the first step, the infrastructure should enable multiple participants to access the ecosystem services and empower data sharing. An IDS Connector fulfils this role by supplying the stakeholders with communication protocols and interfaces to the data space services. That includes mechanisms for direct data provision to and retrieval from other IDS Connectors. In the International Data Spaces, several connector implementations are available, differing in architecture and functional scope [14]. In the MVD, we introduce multiple concepts of connectors to define the functionalities within the MobiDS Use Cases. These concepts are the Mobility Source Connector (MSC) and the Mobility Platform Connector (MPC), divided by the functional requirements they need to fulfil for the use cases.

We defined the functional goal of the MSC to cover the process of data sharing for the MVD, including the description of meta data resources and contracts. For rapidly changing contents, we can add existing Source System APIs for the data sharing process. The MSC manages the metadata for these resources within the connector as an RDF, allowing arbitrary domain-specific annotations from the data sovereign. As the shared datasets might be protection worthy, the MSC can interpret the IDS Policy Language in its entirety, allowing data providers to define custom usage contracts and attach them to the shared artifacts.

The MPC implements the data-receiving component in the use-case scenarios. The initial functionality is focusing on data processing tasks. The MPC offers interfaces for accessing and publishing data at the MDM. It manages content received from other connectors and offers the possibility to merge them with contents from the MDM. Data apps, handling the processing, operate within an en environment provided by the MPC. The communication between data apps, the internal interfaces to the connector, but also communication to the outside world is intercepted and governed by the MPC.

Data Lifting Concepts and Metadata Mappings

Various source systems contain valuable metadata, but are heterogeneous in terms of format (CSV, JSON, XML, etc.) and schema. Mapping approaches are required to make use of these information in the Mobility Data Space. We propose a fully-automatic metadata mapping as follows. The input for such a semantic mapping is metadata in a custom, structured format and schema. The output is metadata in the RDF turtle format that complies to the MobiDS metadata schema, and optionally contains additional source-specific fields. Our approach uses the RDF Mapping Language [15] and follows multiple steps. Together with domain experts, we first define mappings that map one or more fields from the input file to one or more triples (subject - predicate - object) in RDF. For example, a JSON key-value-pair `"ModelContract": "https://[...]contract.pdf"` will be mapped to `ids:ContractOffer ids:contractDocument "https://[...]contract.pdf"`. Note that these mappings have to be defined only once per source system, and can be executed fully-automatically for any instances afterwards. We published a complete example at [16]. On a long-term vision, these mappings should be defined once for each source system and subsequently included into the MobiDS for automatic integrations of large dataset quantities.

Metadata Broker

The initial version of the metadata broker is a derivative of the IDS Metadata Broker reference implementation. We altered user interfaces to fulfill the needs of the mobility domain, supporting the display of the currently used metadata in the MDM and in the mCLOUD [17], as specified in the MobiDS Ontology. Users can provide spatial positions together with references for data schema descriptions like DATEX II. Filtering and search options include NUTS codes. Based on the use cases, first datasets of the MDM are already mirrored at the metadata broker through an automated metadata conversion pipeline, mentioned above.

4. First adoption, scaling, and new business opportunities

Emerging from the first implementation of the Mobility Data Space as R&D project, which demonstrated its feasibility, the project is being transitioned into large-scale implementations of the MobiDS concepts. The future National Access Point (NAP) for traffic and mobility data, which will supersede the current Mobility Market Place (MDM), will incorporate MobiDS concepts, such as connectors to securely exchange data and utilize them in a protected data app environment on the platform. Further, the German federal government picked up the Mobility Data Space approach and initiated a broad stakeholder process of the German public and private mobility sector to found the „Data

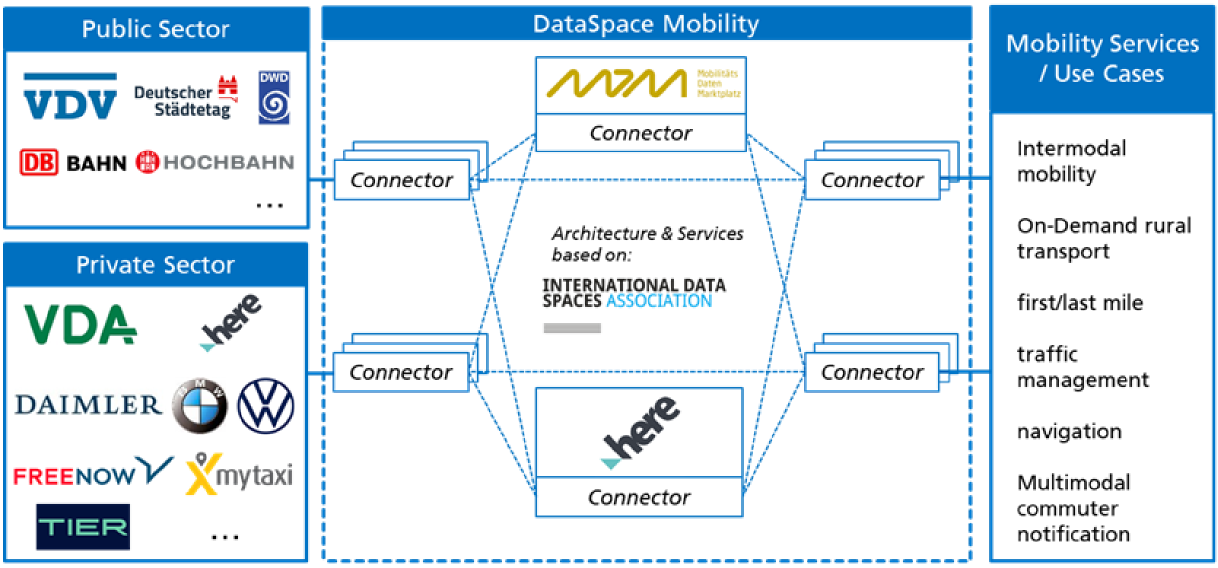

Figure 4 – DRM partners and ecosystem

Space Mobility“ (DRM), coordinated by the German Academy of Science and Engineering (acatech), which will be operated by the Mobility Data Space project in a first demo implementation. The DRM is envisaged to be scaled up with much more participants as an ecosystem and with new use cases. Especially the combination of the decentral data space concept with central MobiDS services requires new governance structures. In order to perpetuate the operation of the central tasks, a newly founded corporation undertakes the management and operation for the DRM. The DRM widens the scope of the current existing mobility data ecosystem of the public sector also to embrace the private, and especially the automotive sector. Figure 4 depicts the planned ecosystem and its architecture, incorporating public and private stakeholders and respective platforms.

In 2018, German Chancellor Angela Merkel’s cabinet initiated the National Platform Future of Mobility (NPM) [18]. Under the leadership of Germany’s Federal Ministry of Transport and Digital Infrastructure (BMVI), NPM has been tasked to enable a transition toward better, more sustainable and affordable mobility while ensuring economic competitiveness and compatibility with German culture. NPM has invited the country’s most affected, influential and innovative actors, such as automakers, unions, R&D experts and consumer protection agencies, to help shape recommendations for decision-makers [19]. Since then, six working groups (WGs) have developed first recommendations. One of the working groups, WG3 on digitalization, proposed testing out first recommendations in real life. This idea ultimately turned into a real-world laboratory initiative in the city of Hamburg or RealLabHH.

In 2020, Reallabor Hamburg or RealLabHH was kicked off with funding from the Ministry of Transport (BMVI) and organized under the auspices of Hamburger Hochbahn [20]. One project of RealLabHH was proposed by Deutsche Telekom and is focused on implementing a first mobility data space demonstrator inspired by GAIA-X and based on IDS technology with an intermodal travel application for illustration purposes (see Figure 5). NPM had been approaching data infrastructure from various angles for some time. The automotive industry had, for example, proposed a “NEVADA Share & Secure” or “neutral server” concept written by VDA [21]. Deutsche Telekom's project, which is

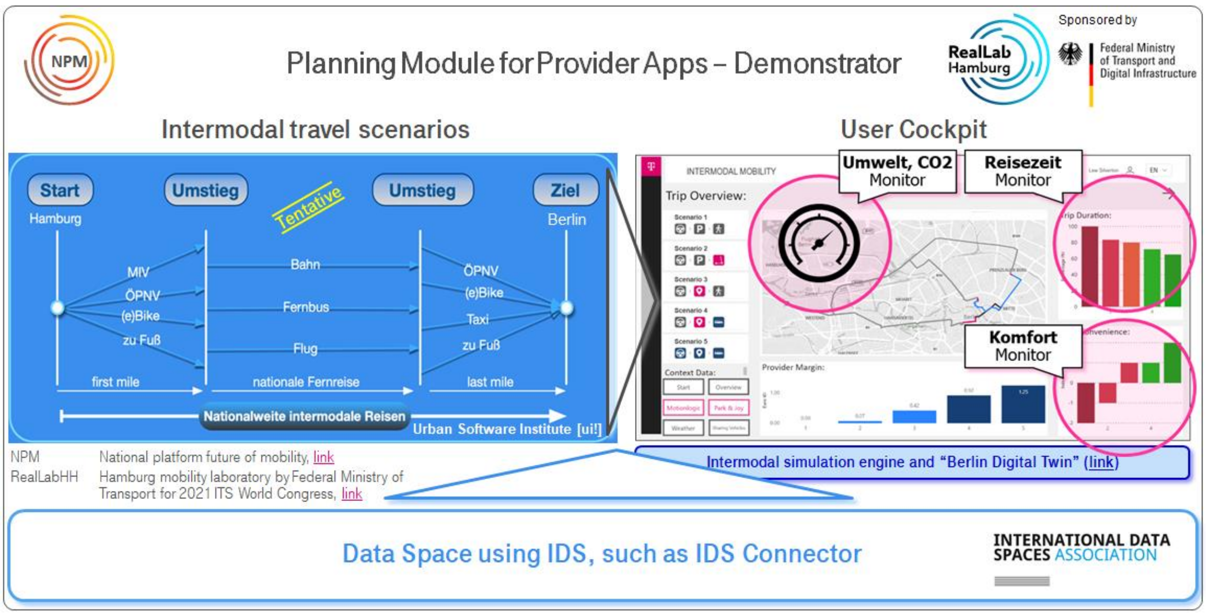

Figure 5 – IDS@Reallabor Hamburg

conducted jointly with the Urban Software Institute (ui!), will demonstrate how an IDS-based data infrastructure can enable the use case of an intermodal, door-to-door travel service between Hamburg and Berlin [22]. Intermodal travel describes the integration of different transport alternatives, such as micromobility, public transport and on-demand shuttles, into a seamless customer journey [23]. Why chose intermodal travel? For one, it would benefit multiple stakeholders: citizens benefit from improved travel options, mobility providers from new business opportunities and cities from cleaner air (for travel speed advantages, see [24]). For another, it presents a difficult data harmonization and coordination problem as well as data sovereignty challenge, and therefore, an ideal opportunity for the application of IDS [25]. Intermodal requires data interoperability and data sharing between multiple companies, such as different platforms (for example, Hamburger Hochbahn's Switch or Jelbi by Berliner Verkehrsbetriebe, BVG) and mobility providers (such as MaaS operator Free Now or micromobility provider Tier), who have so far been reluctant to share their data, also for fear of competitive disadvantages. This is a particular concern with regard to customer data (as opposed to route network, timetable and weather data), which on the one hand has to be treated to be GDPR-compliant [26]; and on the other hand, can be a source of competitive advantage, such as with the personalization of offers and services using recommendation systems, for example [27], which can stoke fear of disintermediation of existing vendors and channel participants [28]. Furthermore, the intermodal travel use case requires IDS to make connecting to it economical for providers, ideally fashioning a loosely coupled, tightly integrated system that provides sufficient integration for trusted transactions while maintaining flexibility to quickly link up and reconfigure with new partners or cities [29]. From an information systems architecture perspective, this is quite similar to the shift that has been overserved at the application layer with the emergence of web services and their evolution toward microservices [30]. It is this confluence of strategic and operational data coordination and sovereignty challenges that makes the intermodal travel use case a rich application domain to prove the relevancy and potency of IDS. In order to speed up development and ensure operational stability, the RealLabHH demonstrator will leverage existing partner assets, such as the Telekom Data Intelligence Hub [31] and UI UrbanPulse [32]. Specifically, the mobility data space demonstrator will deliver: (1) A functional planning demonstrator including user interface for an intermodal travel application (B2C interface, see right part of Figure 5) as a plug-and-play module for existing mobility apps (B2B perspective). (2) An IDS-based data link layer using core IDS components, such as connector, as a prototype mobility data space. (3) New value-added data services for a n:n federated data organization to link the app module with the data space.

DRM, NPM and RealLabHH align to support the data strategy of the German federal government as well as the European Commission. They combine to further accelerate the build-out of pan-European GAIA-X as a secure and federated data infrastructure for a variety of sectors. First-mover projects like MobiDS and RealLabHH are already serving as foundations for first demonstrations. These market-oriented developments are reinforced by regulation, such as the call for National Access Points (NAPs) in the Delegated Regulations of the European Commission under the ITS Directive [5]. Those NAPs are seen as the backbone for the European Mobility Data Space. The NAP Coordination Organization for

Europe (NAPCORE) will federate the NAPs in Europe. BASt will take a leading role in this organization and promote MobiDS concepts for interoperable implementations in the NAPs for secure and sovereign exchange of mobility data via the NAPs. The German NAP, the Mobility Data Marketplace, is currently under fundamental revision and will be upgraded using MobiDS concepts into a platform with greatly expanded capabilities and functionality.

5. Conclusion and outlook

The Mobility Data Space will allow for a leap in mobility capabilities, opportunities, and end-user benefits because it will protect data sovereignty. In the past, such progress has been inhibited by a lack of data sharing. Now, existing platforms and competing mobility providers that may not trust each other can interconnect and trust data sharing transactions. Usage control will enable the securely controlled exchange and processing of sensitive mobility data. With IDS-based data spaces any participant can determine what happens to their data and define how, when and at what price others may use it across the mobility value chain. It sounds good on paper; the gamechanger have been those first real-life implementations described in this paper. They proof applicability of the collaboratively-developed concepts and realizations of the IDSA community in the mobility sector, as well as readiness of the technology. So far, governments have been most supportive providing strategic direction. The data strategies of the European Commission and the German federal government are a case in point. They also have seeded the step from paper to practice. Examples include the pan-European GAIA-X data infrastructure, the IDS technology standard, first data space foundations, such as the German Data Space Mobility using MobiDS, and numerous publicly funded research and development projects like RealLabHH to encourage co-creation of use cases and end-user applications with mobility providers and the public. Governments have also promoted an open, collaborative and consensus-style rollout to facilitate interoperable data spaces with common rules. This is where associations such as GAIA-X AISBL (association internationale sans but lucratif, headquarters in Brussels) and the International Data Spaces Association (IDSA) have been paramount. For example, IDSA has been spearheading IDS adoption with operational, vital market-making activates that range from setting up a certification pipeline and rulebook writing to providing boot camps. This is good to know for the business community. There is strategic as well as operational backing to support adoption of data spaces. Now would be an opportune time for businesses to take advantage of first implementations, such as MobiDS, which is accelerating the implementation of remaining functionalities in its minimal viable demonstrator. It provides a setting for various stakeholders to experiment with improvements of existing products or creation of entirely new offerings, such as intermodal travel, or even the exploration of new roles and business models, such as service orchestration – all in a safe, secure environment with data sovereignty protection.

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