DELIVERABLE T.1.1.1

Managerial approach on data-based planning for energy-efficient public transport infrastructure

Project index number and acronym	CE1537 EfficienCE
Lead partner	PP1 – City of Leipzig
Deliverable number and title	
Responsible partner(s) (PP name and number)	PP 1 - LEI PP 2 - LVB
Project website	www.interreg-central.eu/efficience
Delivery date	
Status	Draft version 1
Dissemination level	Confidential

Document history of revisions			
Date	*Name*	*Action*	*Status*
06.10.2021	Marlene Damerau Rupprecht Consult	Structure and brief content description	Template
31.05.2022	Sebastian Graetz, City of Leipzig	Content writing	Draft
30.06.2022	Marlene Damerau, Rupprecht Consult	Content writing	Final

0 Abstract

Data-sharing and analysis can create value for public transport (PT) infrastructure planning, as it helps understanding and predicting, e.g., energy needs, wear and tear of infrastructure, and current and future user needs. The City of Leipzig (DE) together with its PT operator Leipziger Verkehrsbetriebe (LVB, DE) developed an explorative use case for energy-efficient PT infrastructure planning to test their urban data platform (UDP), deriving additional value from existing data by making them more accessible, using the UDP as transformative tool for unlocking data silos. The present document explains their managerial approach to implementing and testing the UDP in a transferable way. Thus, the context and framework of a UDP can be outlined in a paper of understanding, followed by setting up the right working structures, and defining the process and common principles. The clear definition of a vision, objectives and scope for the UDP are crucial, such as 1. ensuring data sovereignty via self-determined data infrastructure, 2. supporting integrated urban development through smart city management, 3. enabling policymaking, target monitoring and the preservation of the state's ability to act and diversity of options. Also, a suitable business architecture considers how value is created, which stakeholders and roles, skills, governance model are needed, and defines existing risks. The information architecture should consider which data are exchanged and how. By deciding for a state-of-the-art reference architecture, defining interfaces, applications, systems, and network infrastructures for data-sharing is facilitated. Furthermore, it should be defined how and for which application domains the UDP is used. Expert recommendations specifically designed for the Leipzig UDP implementation and testing are described, followed by a summary of the EfficienCE use case and lessons learnt for data-based planning.

1. Testing an urban data platform: explorative use case for data-based planning

Analysis of data can create value for public transport (PT) infrastructure planning, as it helps understanding and predicting, e.g., driver behavior, wear and tear of infrastructure, and current and future user needs. Thus, the generation, storage, and sharing of relevant data between city administrations and public transport operators (PTO), and their procession through statistical or machine-learning analysis can lead to insights and predictions that help reduce waste, improve energy performance, infrastructure maintenance, and lead to a better understanding of future investment needs.

The City of Leipzig (DE) together with its PT operator Leipziger Verkehrsbetriebe (LVB, DE) developed an explorative use case for energy-efficient PT infrastructure planning based on shared data to test and further develop their urban data platform (UDP). The UDP is an instrument to facilitate systematic data-sharing between city departments and utilities based on a standardized approach and a set of rules. While the more general objectives attributed to the UDP are to improve services and to increase the quality of life, the goal in the EfficienCE use case was 1. to understand the organisational and managerial requirements for data-sharing with the help of an UDP, and 2. to understand how the UDP can be applied to increase PT infrastructure's energy-efficiency.

In the following chapters, UDPs and the context for implementing one in Leipzig are described, followed by organizational lessons learnt from the EfficienCE use case for introducing systematic data-sharing through an UDP. A summarized description of the EfficienCE use case and data-based lessons learnt by the partners is given[1], and other good practices for UDPs are referenced.

As the EfficienCE project used the sustainable mobility planning (SUMP) concept as general framework for energy-efficient PT infrastructure planning, an adapted version of this framework[2] was also used to describe the managerial approach for data-based planning in the present document.

2. Urban data platform in Leipzig as transformative tool for unlocking data silos

The Urban Data Platform (UDP) Leipzig is to provide municipal data-based services and offers. These are to be made available to municipal companies, city administration, the economy, science and civil society under defined criteria.

In September 2019, the Digital Services Advisory Board of the Lord Mayor of Leipzig therefore commissioned a core working group consisting of the Digital City Department, the Leipzig Group, Geodata Information Leipzig and Lecos GmbH to put the systematic use of data in the city of Leipzig on a new footing from 2021 onwards by developing a concept for the Urban Data Platform. This also includes the integration of new services and applications of the digital city, such as data use based on a wide variety of sensors in the urban area. The first pilot applications and corresponding transmission networks are being tested in the environmental sector and mobility sector.

As part of the smart city model project "CUT - Connected Urban Twin" funded by the Federal Ministry of Housing, Urban Development and Building (BMWSB), Leipzig is improving its UDP and developing a digital twin with the cities of Hamburg and Munich.

Why an UDP? Overcoming data silos

The city of Leipzig, the Leipzig Group and other municipal players manage extensive information and data stocks of various kinds in largely isolated management systems (see Fig. 1 for data silos). These data consist, among other things, of official data from administrative tasks, company data, data from municipal companies or data from sensors in the public space.

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[1] For more detailed description please refer to D.T1.2.3 Action Plan for energy-efficient PT infrastructure deployment (UDP use case Leipzig & LVB) and O.T1.2.1 Output factsheet Action Plan for energy-efficient PT infrastructure deployment (Leipzig & LVB UDP use case)

[2] For the German RAIM framework the SUMP concept was adapted for guidance to developing data-based mobility services: RAIM-Architektur.

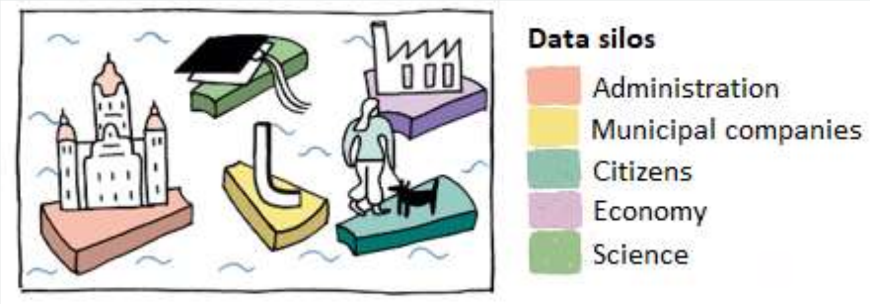

Figure 1: Data silos (data islands)

The problem that the UDP helps to overcome is, that data exchange currently takes place only on a case-by-case basis. In accordance with their diversity, municipal data are currently still subject to many different regulations and cultures of collection, processing, storage, (non-)disclosure and publication. To derive additional value from the existing data (valorization), it is necessary for the city administration (incl. the municipal enterprises) and the Leipzig Group to make their data resources more accessible in the future, for example, to make interoperable services usable.

A systematic, networked and standardized approach, including a uniform set of rules, can enable benefit in terms of sovereignty over data and data infrastructure, smart city management, smart urban society and data-based innovation. To be able to start working, it is recommended to jointly agree on context, framework, joint principles, and to set up joint working structures.

2. Prepare well before implementing a UDP

Define context and framework

To create the necessary technical and organizational framework within the city administration and in conjunction with the municipal companies of the city of Leipzig, an initial "Understanding Paper Urban Data Platform" was drawn up in 2020 by a core working group composed of interdisciplinary and interdepartmental members.

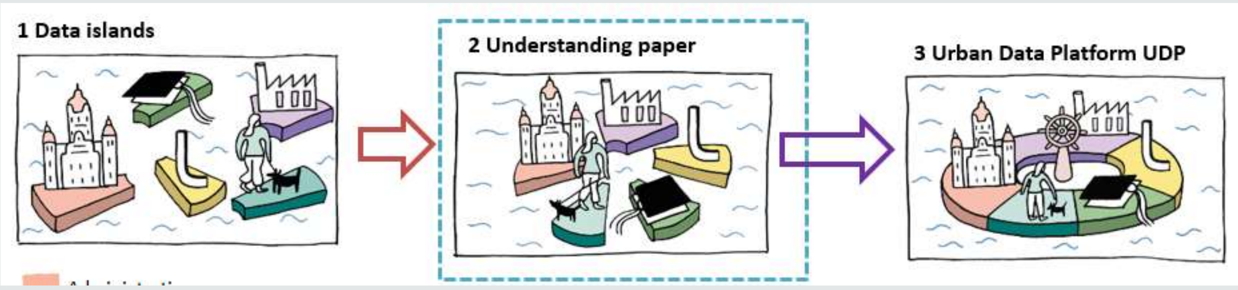

Figure 2: Development of data islands into an urban data platform

Set-up working structures and paper of understanding

The City of Leipzig, together with the municipal utilities and representatives of the L-Group, has founded a core working group "Urban Data Platform Leipzig". The UDP core working group consists of the Digital City department, the Office for Geoinformation and Land Use Planning, Kommunale Wasserwerke Leipzig

GmbH, Leipziger Versorgungs- und Verkehrsgesellschaft, Leipziger Stadtwerke GmbH and the municipal IT service operator, Lecos GmbH.

The paper of understanding defines initial terms and basic guiding principles for the development of an UDP infrastructure for the city of Leipzig. This includes, among other things, the understanding that digital data will be understood even with greater interdisciplinary and interdepartmental commitment in the future, as a central "resource" for future urban development and that it will be tapped in a correspondingly holistic and sustainable manner. In concrete terms, innovative data-based applications should help to achieve the goals of the integrated urban development concept of the city of Leipzig in the best possible way.

The paper of understanding provides an initial framework. The successful and sustainable operation of an UDP requires not only the purchase of software and hardware products and the deployment of data analysts, but also the recognition of the need for adaptation, the enlightened handling of urban data (less in terms of technical understanding than in terms of skills, acceptance, transparency and digital ethics) and the provision of necessary resources.

Define the process and common principles in a “target and implementation concept”

In the second step, the findings and framework conditions are translated into a target and implementation concept. The core element here is the transparent clarification and coordination process led by the core working group. By involving top management, policy makers and data ecosystem stakeholders in the content, the Urban Data Platform is to be founded on acceptance and co-determination right from the start. In addition, the concept can only develop an action-guiding force if in the end there is not only a coherent text, but also an internalized understanding of the roles and tasks of the actors in the data ecosystem of the digital city of Leipzig.

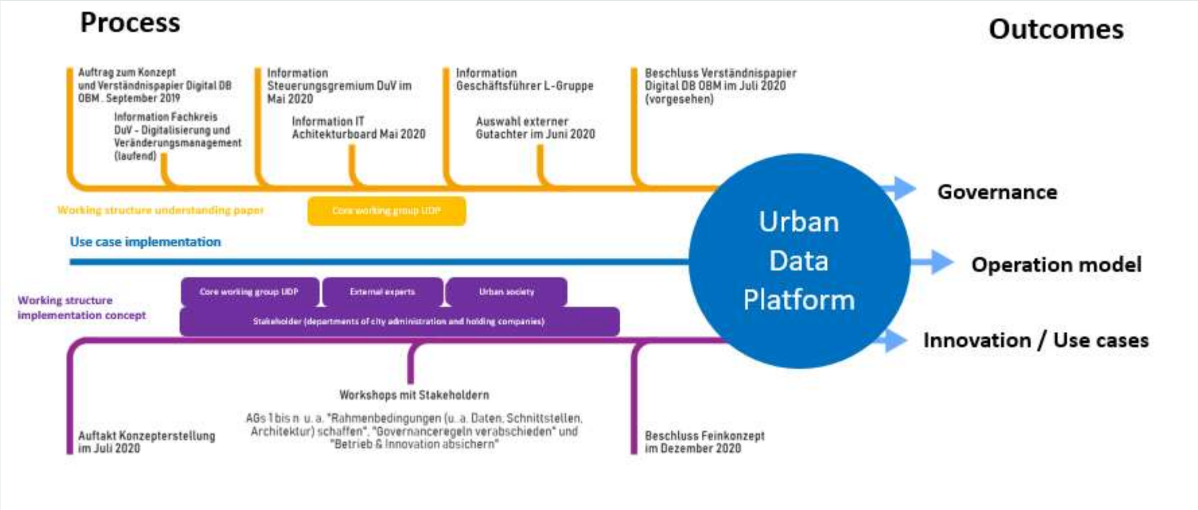

Figure 3: Development process of the city administration and the associated companies (In orange: Structural result of developing a common understanding).

The basis for the cross-actor development of the UDP is a common understanding of central terms, as well as a common image and joint objectives for the use of an UDP (see chapters 3, 4).

Urban data space

The field of action and the impact boundary of an Urban Data Platform is essentially determined by the Urban Data Space. A coherent explanation of the term is provided by the study "Urban Data Spaces" published in 2018 by Fraunhofer FOKUS[3]. Derived from this, the following definition emerges for the city of Leipzig:

The Leipzig Urban Data Space includes all types of data that may be relevant for the municipal community, economy and political space of Leipzig. It contains all data relevant to the city of Leipzig and its stakeholders from all subject areas (energy, mobility, environment, health, culture, etc.) that arise in the context of analog and digital city life. The boundary of the Leipzig urban data space does not necessarily end at the city limits, but can also be shaped by economic, environmental and social areas.

Urban data platform (UDP)

The UDP consists of a technical and organizational core that meets the requirements of the various actors and of the Urban Data Space in general. Thus, theUDP is not exclusively a service-oriented infrastructure for networking data, but also an intellectual approach that connects the city's actors with each other:

The UDP is a coordinated core component of the digital city consisting of technical and organizational components. The goals of the UDP are to provide easy access to urban data from different sources and to make multiple use of the analytical capabilities of existing IT systems and IT services. The UDP is designed to enable the availability of data and services to specific audiences to inform, support or make decisions. The UDP follows the principle of a "system of systems".

Figure 4: Central terms from target and implementation concept in Leipzig

The Leipzig guiding principles define a common understanding related to ethical, technical and non-technical principles and requirements for the use, further development and operation of the Urban Data Platform. They are intended to serve as a compass for all decisions related to the Urban Data Platform.

- Data ethics

The Urban Data Platform is oriented toward the common good. The needs of urban society - such as transparency, participation, integration, resource conservation, efficient action, and promotion of prosperity and quality of life - are at the center. Data protection, data security, data economy and municipal data sovereignty are the responsibility principles that determine the technical architecture and the rules of use.

- System of systems

The Urban Data Platform is a network of existing and future systems based on interfaces. Capabilities and resources of the systems are linked, thus enabling multiple use of data and functions. As a service layer, the urban data platform strengthens and complements the individual systems. It therefore contributes to collaboration and resilience.

- Modularity

The Urban Data Platform is a modular system that is expanded based on concrete use cases and needs. The modular approach enables open source and commercial solutions. However, a permanent dependence on manufacturers is to be avoided and medium-sized research & development is to be strengthened

- Data availability

The stakeholders responsible for the data make existing urban data, as well as new urban data to be developed, available digitally in a usable form in compliance with the law. They support the principle of making data available as widely as possible and determine the scope of data release according to a

[3] Study "Urban Data Spaces" by Fraunhofer FOKUS (https://www.fokus.fraunhofer.de/de/fokus/presse/urbaneDatenraeume-Studie-Datenmanagement_2018_06)

common set of rules. The Urban Data Platform supports the actors responsible for the data in the process of making it available and releasing it.

- Data sharing

The actors responsible for the data provide their data for the Urban Data Platform according to a common set of rules and thus enable multiple use, enrichment and linking. Urban data can thus be used independently of the technical, content-related or organizational context in which it was created. The permitted multiple use and linking enables publication as open data and the development of innovative urban applications.

- Standardization

The Urban Data Platform can integrate other systems based on interfaces. It can provide data, services and applications for internal and external systems, considering the standards. It thus fulfills the core requirement for interoperability and API orientation.

The Urban Data Platform uses existing standards and strengthens higher-level processes of standardization (in both technical and non-technical dimensions). The actors responsible for data and systems also seek the orientation towards standards.

3. Clearly define vision, objectives and scope for UDP

A political decision is the starting point for developing a UDP. E.g., the City of Leipzig defined the concept and development of its UDP as one of its strategic priority projects in 2019. Furthermore, it is important to define what the UDP should serve for, with clear objectives and the scope for its application.

The vision for the UDP is:

To ensure data sovereignty via self-determined data infrastructure

As producers, trustees and owners of urban data, the partners in the operator model of a joint urban data platform know their own data stock. They can efficiently store, exchange, process, refine, and make the data available via urban applications for their purposes of providing public services and maintaining the ability to act.

While retaining their independence, the partners involved jointly lay down the digital rules of the game in the secure and comprehensive handling of urban data. They can determine the value of urban data and decide in a coordinated manner how they want to handle the data.

The participating partner organizations understand data sovereignty as empowering the actors of the urban data space to understand and use digital technologies according to the state of the art and to share data in a trustful way.

The partner organizations involved can choose freely between services and technical solutions, can draw on their own resources or combine external procurement and in-house development.

To support integrated urban development through smart city management

By supporting information, planning, control and simulation tools as well as effective analytics and decision support, institutional modernization and cross-cutting processes improve system performance, data availability, and urban quality of life (e.g., public services, infrastructure, climate mitigation/adaptation, value creation, services).

To enable policymaking, target monitoring and the preservation of the state's ability to act and diversity of options.

The Leipzig UDP is used to implement its political objectives with defined targets (e.g., air quality targets) and KPI, such as the municipal “Mobility Strategy 2030”, and to support the city – selected as model city by the European Commission in 2022 – in becoming climate-neutral by 2030.

To support reaching these objectives, the UDP is to provide easy access to urban data from a variety of sources and multiple uses of the analytical capabilities of IT systems and IT services. The UDP should aim to enable the target group-specific availability of data and services to inform, support or make decisions.

Thus, the scope of the UDP is to facilitate performance monitoring based on given objectives and shared data. To measure progress, indicators suitable to measure progress are needed, as well as good practices to inspire further use cases for data-based planning (see fig. 5 good practices).

Objectives should be defined in a measurable way, together with suitable key performance indicators (KPI) that support monitoring progress in achieving these objectives. Sustainable urban mobility indicators are a useful tool for cities and urban areas to identify the strengths and weaknesses of their mobility system and to focus on areas for improvement. As cities and urban areas continue to develop Sustainable Urban Mobility Plans (SUMPs) and work towards EU policy goals, it is important for this progress to be documented to ensure that such achievements become visible. For data-based planning and monitoring, these indicators can be useful. The European Commission has therefore developed a comprehensive set of practical and reliable indicators that support cities to perform a standardised evaluation of their mobility system and to measure improvements that result from new mobility practices or policies.

Weblink: https://transport.ec.europa.eu/transport-themes/clean-transport-urban-transport/sumi_en

Figure 5: SUMI indicators can assist in data-based monitoring and planning

4. Define the business architecture of your UDP

Value creation

It is recommended to define how a UDP is going to create value for the participating stakeholders and users.

The City of Leipzig decided that the added value of the UDP is to facilitate information, planning, control, and simulation to improve system performance and quality of life by ‘urban applications’. As instrument for integrated (digital) urban development, the UDP serves to better open the data space in technical, organisational, regulatory, and participatory terms. The systematic use of data should help to improve services of general interest, increase the quality of life and the growth opportunities of regional companies.

Urban applications

Based on integrated data and services, the Urban Data Platform is to provide suitable applications that functionally support urban processes and provide targeted information:

Urban applications solve specific questions and problems for specific target groups by using urban data and linking services. The prerequisite for urban applications is the provision of standardized services and metadata

Figure 6: Central term from Leipzig target and implementation concept

Being a "system of systems", the UDP provides its own services and applications based on intelligently networked data but also depends on and complements the specialist services and capabilities of the data-carrying systems (e.g., specialist information systems, ERP platform, IoT platform). The UDP thus contributes to process efficiency, but also to resilience. The ability to support or prepare decisions is strongly dependent on the data basis and the available technologies and is subject to data protection, data security, and economic and ethical guiding principles.

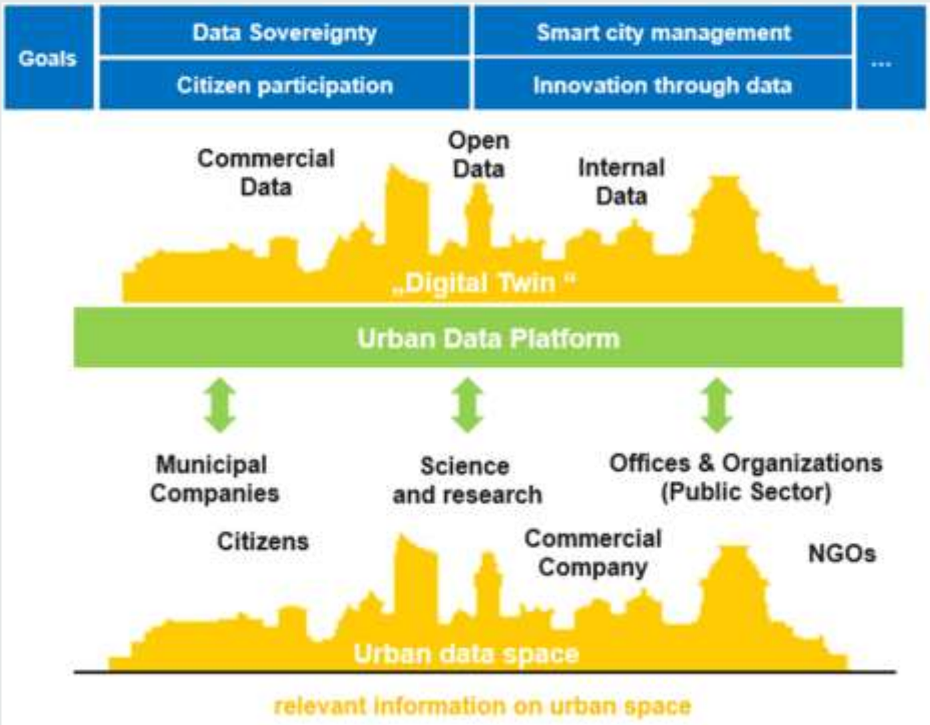

Figure 7: UDP goals and system delimitation

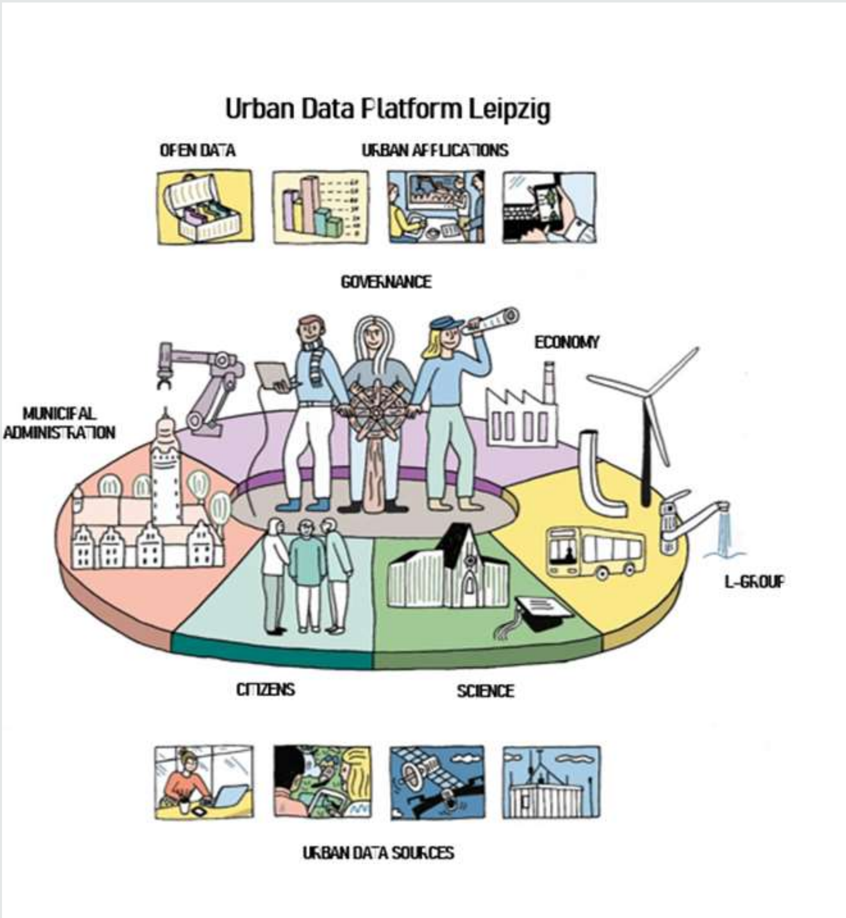

Figure 8: Target image of the Urban Data Platform

Stakeholders and roles

It should also be defined which actors with which roles need to be included into the value creation chain. For the Leipzig UDP, the main actors for developing and testing the UDP are:

- Digital Services Advisory Board of the Lord Mayor of Leipzig: responsible to politicians and the public.
- Digital City Department: as mediator and network organiser.
- Leipzig Group (utilities with LVB): data owners, provide access to raw data, develop solution for increased productivity and cost production (e.g., EfficienCE use case), use services.
- Geodata Information Leipzig: central agent for developing the UDP / data aggregator, owns central control of data quality, facilitates formalised provision.
- Lecos GmbH: the municipal IT company, implements and maintains UDP.
- The transportation and civil engineering office, actors responsible for the mobility strategy, climate protection programme (e.g., air quality management): data owners, provide access to raw data, use services developed based on data-sharing

Which skills should these actors have?

Data analysts are needed to enable data-based decision-taking in organisations. On a more general level, it is important that stakeholders understand the need for adaptation, the enlightened handling of urban data (less in terms of technical understanding than in terms of skills, acceptance, transparency, and digital ethics) and the provision of necessary resources. This means, fostering data literacy and understanding about hardware, software, artificial intelligence, digital twins, is important to support acceptance towards data-driven monitoring and decision-taking.

An important lesson learnt by the Leipzig partners is that buy-in of experts can only support to initiate this process, but that change needs to come from within organisations, based the “coalition of the willing”.

Governance and cooperation

To regulate the cooperation of these actors on the legal, organisational and technical level, a governance model and a data strategy are needed. Seen as the most difficult part of the process, the City of Leipzig is tackling the definition of a legal and organisational framework in a follow-up project.

A data strategy defines how data will be shared, with standards for documentation, quality, infrastructure, security and protection, internal and external access regulation, and operational objectives. It also defines how to manage risks.

A governance model defines the roles and access rights of the stakeholders and data users. Possible models are open access model (providing free access to information and unrestricted use of resources for everyone”; restricted access model (different types of user access can be defined based on bilateral arrangements where terms depend on use, quantity of data, or similar). Compliance with relevant laws (e.g., privacy or competition laws) needs to be considered in all models.

Risks

Possible risks associated with the UDP implementation and use should be identified. The City of Leipzig recommends to not depend on IT companies to avoid being in closed systems, and to better use open systems.

Further risks are related to the protection of personal data, the economic value and proper handling of data and publication obligations, and the avoidance of dependencies on third parties (e.g., Internet and software corporations).

4. Define the information architecture of your UDP

The stakeholders participating in the UDP need to define which roles need to exchange which data with each other, and to decide which standards should be used for information exchange of actors, to ensure data accessibility through the vertical and horizontal structure of the organisation(s). All stakeholders of the local authority family should organise their data access via the UDP as a data hub. The focus should be on a (fully) automated process with dynamic processing of a wide variety of information from different data sources as well as their provision, aggregation and comparative analyses (benchmarking). In parallel, the raw data model and, if necessary, the analysis results should be automatically fed back into the UDP, to provide the data and insights gained to the municipal structures.

Data management and transformation of raw data into knowledge

Digital transformation requires open urban data platforms that can be used by administrations, companies and other market participants to provide services more efficiently and in a more targeted manner.

The joint and multiple use of already available urban and regional data via a UDP faces various challenges, but also promises a high synergy potential for the city of Leipzig through the networking of data sets. The data must be collected in a structured manner, and the data structures must be adapted to each other or standardized. Furthermore, it is necessary to provide interfaces and to ensure the continuous updating of data. The use of standardized platforms facilitates these processes.

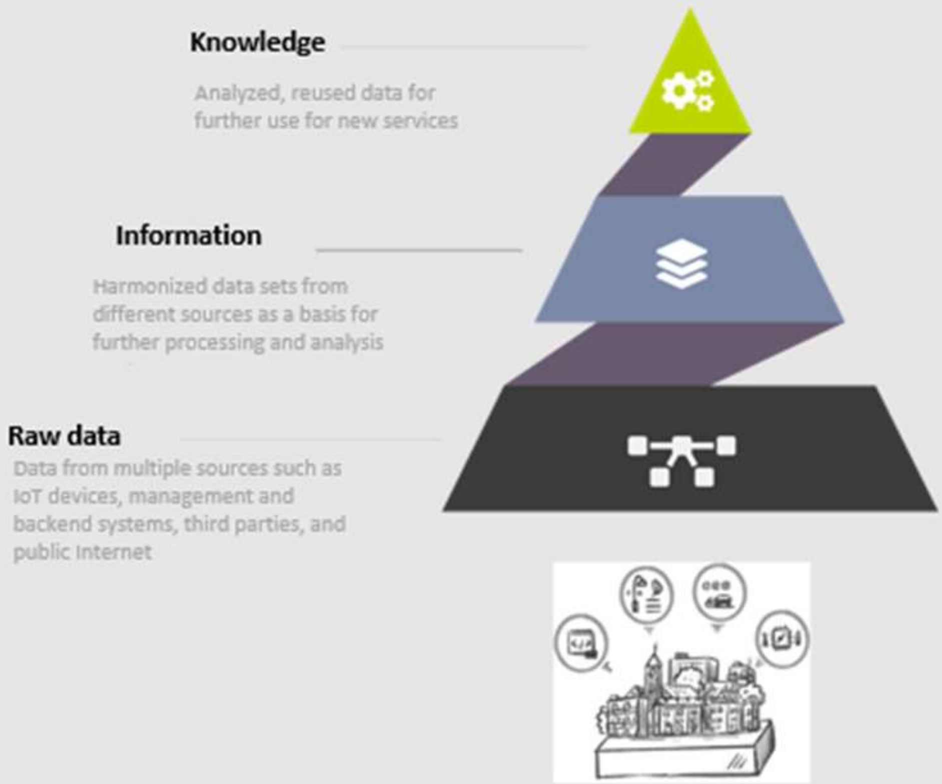

Figure 9: Data transformation in an urban data platform

When managing data, it is important to remember that not all data is the same (see Fig. 6). Raw data is understood to be the data brought together from the various systems in unchanged form. Information refers to the data generated from the raw data by synthesizing and harmonizing the raw data using software modules. Information refers to a uniform data model within the UDP. Knowledge describes that data which is generated with the help of software analysis tools such as machine learning modules. Based on such software modules, urban developments can be observed and analysed, for example, and provided automatically to various applications as decision-making aids in the form of smart data.

A typical challenge occurs due to the heterogeneity of the data and as well as the distributed responsibilities for certain data across different offices of the city of Leipzig and the companies in the city group. Access to data sources is a central task for UDPs. Data is transferred to a data platform via interfaces of the data provider systems with the help of so-called connectors. These connectors receive urban data, aggregate and refine it already partially and transfer it into a normalized, i.e. unified, form. The refinement enriches the data, e.g., with geo-coordinates stored in the metadata, to make it easier to display on a map view. Through the normalized form, further processing is simplified. If, for example, forecasts are to be made on environmental data, a forecasting service must be able to process only one data format, even if sensors collected the data from different manufacturers.

One approach to build powerful and demand-driven open data platforms, regardless of future developments, is to digitize all information in such a way that the heterogeneous data can be restructured and used repeatedly as needed.

Urban Data

The data-holding actors from administration, business, science and civil society have a growing pool of data at their disposal. The central task of the UDP as the basis for a functioning data ecosystem (including, for example, open data portals, map or IoT applications) will be to recover this data and make it available to the digital city in various internal/external forms.

Opening up data silos that exist in isolation from one another is the first and most important step toward value chains. Linking and enriching the raw data as the next step creates new customized data sets (secondary data) that form the basis for further services and applications. In the totality of raw and secondary data, we speak of urban data. (see **Fig. 6** Data transformation in an urban data platform)

*The term **urban data** includes all data that can be produced, maintained, used and made available in a structured way by public actors (e.g. public administration, urban enterprises, civil society), private actors (e.g. companies, foundations) or other subjects or objects (e.g. sensors, actuators). The urban data contains relevant information about the urban space of Leipzig.*

Figure 10: Central term from Leipzig target and implementation concept

In general, it can be assumed that the variety and amount of urban data, the amount of data-carrying actors, and the physical objects that leave virtual data traces are increasing rapidly. This development is driven by advancing digitalization and innovative technologies (e.g., sensor technology, IoT, autonomous driving), public initiatives, and data-driven business models (e.g., car and bike sharing). The novel networking and processing of, among other things, personal and activity-generated information gives rise to new data such as (property) rights or data-related (usage) rights or regulatory and data management issues.

Urban metadata

In consideration of a growing amount of data, the users of the UDP must be provided with tools for easy search and assessment (e.g., about origin, quality, and terms of use). From the point of view of the data-carrying agencies, it is also necessary to create possibilities and means with the help of which the data can be described efficiently, in a structured and legally secure manner. Since the expected data volumes can only be analyzed efficiently by machines in the long term, they must be made available in a structured manner. Last but not least, it is the urban metadata and data catalogs that enable the access, usability and thus the value creation of urban data in the first place:

__Urban metadata__ is data about data. They provide structured and machine-readable information to describe urban data. Metadata catalogs can be used to efficiently capture metadata and enable easy access to data. Urban metadata can be integrated into higher-level metadata catalogs via standard interfaces.

Figure 11: Central term from Leipzig target and implementation concept

5. Use a state-of-the-art reference architecture for UDP to define IT interfaces, applications, systems, and network infrastructure for data-sharing

Interoperable standards and interfaces should ensure the continuous updating of data. The use of standardized UDPs facilitates the process.

UDPs received their first reference as a key building block of public infrastructures in the "Memorandum of Understanding - Towards Open Urban Platforms for Smart Cities and Communities" of the European Innovation Partnership "Smart Cities and Communities" (EIP SCC) in June 2015.

The proposed areas of collaboration include:

- Developing a set of principles and a common framework for a reference architecture to enable interoperability, scalability, and open interfaces to integrate different solutions.
- Accelerating the adoption of the developed framework by standards bodies
- Adhere to all common standards and the framework when developing individual commercial smart cities products and solutions
- Collaborate with cities to develop customized operational frameworks

A common reference architecture enables the following:

- Interoperability between urban infrastructures within cities.
- Replicability of solutions/platforms from city to city
- Scalability of solutions without technical constraints and excessive cost implications
- open common interface (APIs) and corresponding tools (SDK) that facilitate the development of applications on the platform by third parties
- a set of functional capabilities and corresponding technical modules based on city needs and supported by city use cases

The concept for the reference architecture should consider the following points:

- Infrastructure
- Data management, including semantics/ontology
- Open interface layer
- Analytics
- Service creation and provisioning
- Security and privacy
- General management services

At the same time as the MoU, work began on DIN SPEC 91357 "Reference Architecture Model Open Urban Platform (OUP)", which was published in December 2017.

Figure 12: Overview of studies and regulations for urban data platforms

According to DIN SPEC 91357, the basic common features of urban (data) platforms are:

- structure as a central instance that bundles data and services, in the form of a system of systems

- two-sided or multi-sided platform, i.e. different systems (so-called data suppliers) can receive, store, analyse and, if necessary, process data via corresponding interfaces. This data is then provided to applications (APPs) or other systems (so-called data users). Thus, the Urban Data Platform unfolds its strength especially when it can be used as an intermediary between different organizational entities
- data flow-based layered architecture from the "source" to the "sink", as the main artifact of the UDP is (urban) data and its processing along a value chain.
- connection of as many different / all (management) systems of a city as possible, as only such a system approach allows the possibility of integration across the entire city group.
- georeferencing and time stamping of data records, i.e., a spatial and temporal reference are of central importance, especially for the growing number of so-called IoT data.

In addition, Urban (Data) Platforms vary by paying more or less attention to the following aspects:

- Agnostic with regard to communication protocols, i.e. the data suppliers are connected using different network and communication protocols.
- Variable storage architecture, i.e. the platform should be flexibly designed for different data profiles. Real-time analysis of data streams require different storage than "Big Data" analysis of historical data. In addition, the costs for storage technologies vary greatly, so that appropriate optimization by the platform can be highly relevant for cost management.
- Virtualization of resources, i.e. the platform must be able to adapt dynamically to the respective situation when resources are required. Cloud-based approaches are therefore usually more efficient and cost-effective.
- Demand-based processing times, i.e. the platform must be geared in particular to the growing demands of real-time-based processing of data streams. Classical data processing (batch, BI reporting) must also be supported as needed.
- Evaluation of the data, i.e. the raw data of the data suppliers must (mostly) be analysed by the platform. Currently, forecasts or event checks are often a central component of smart city solutions, so analytics/KI modules for analyses and forecasts as well as event checks (Complex Event Processing) are necessary in order to provide the data to the data users as needed.
- Security concepts, i.e. how is this central instance protected against possible unauthorized access or even attacks.

Currently, various approaches can be found in the implementation of urban data platforms:

Integrated infrastructure

In accordance with DIN SPEC 91357, an overall system is set up as a "system of systems" in which all relevant components are coordinated with one another and operated as an integrated infrastructure. Care should be taken to ensure that the integration of existing and future systems is carried out using a standardized procedure with as little integration effort as possible.

The advantage of this approach is a coordinated system landscape in which the individual components are aligned with each other. A common data model is used by the components, which supports the reuse and thus the increase in the added value of the data.

Framework approach

In this approach, individual components are selected and then built individually for a solution. Different systems are linked together by generic infrastructure components. In the process, these systems must satisfy common criteria, which they must implement themselves.

The advantage here is the individual selection of components, provided they are supported by the selected framework. With this approach, special attention must be paid to the integration and maintenance effort. Many open source-based platforms are based on this approach.

DIN SPEC 91357 refers to capabilities of open urban platforms as a guide. Thus, an explicit selection of the approach of the municipality becomes possible based on an evaluation of the corresponding capabilities. These capabilities are divided into categories that are essentially based on the various layers of the system architecture.

Table 1: Categories of capabilities according to DIN SPEC 91357

Category	Capabilities
0	Capabilities of the devices and field components: acquire, measure and control.
1	Communication and networking capabilities between field components, back-ends and the platform
2	Capabilities for device management as well as georeferencing
3	Data management and analysis
4	Choreography and orchestration of services and processes
5	Generic capabilities to support urban applications
6	Special application capabilities
7	Interaction and communication with users and systems
8	Data protection and sovereignty
9	General, overarching skills

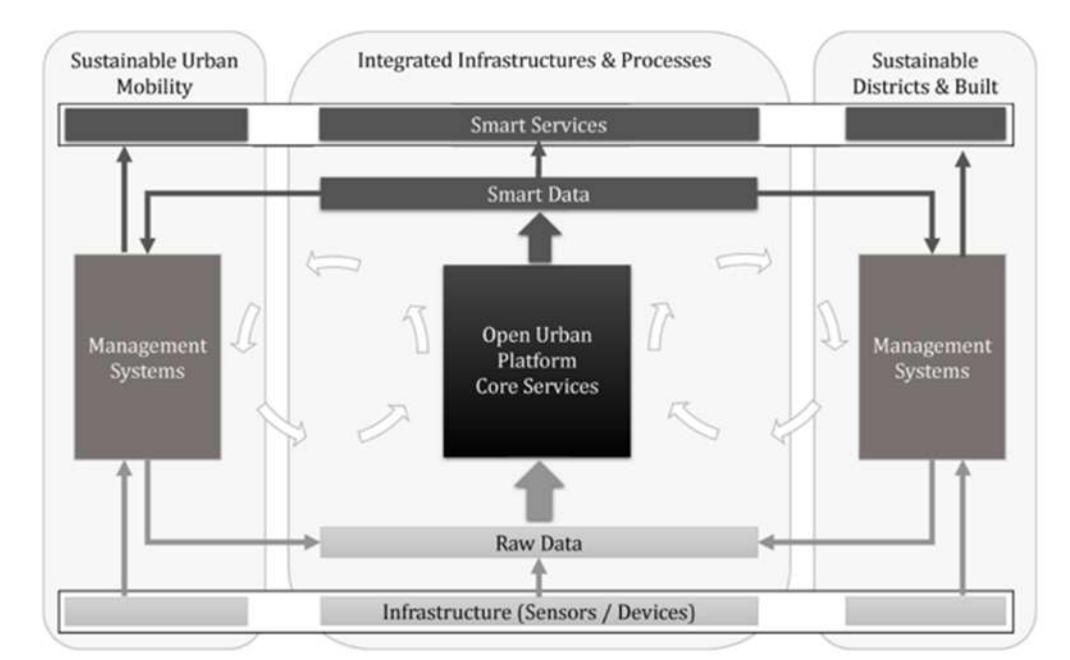

Figure 13: Schematic representation of an Open Urban Platform (according to DIN SPEC 91357).

DIN SPEC 91367: Urban mobility data collection for real-time applications

DIN SPEC 91367119 deals with the topic of an urban mobility data platform with a special focus on real-time aspects and properties of the data, services and applications based on it. During this, various data models are discussed as well as the possible regulating and restricting data access. In addition, data interfaces are defined that enable the exchange between different pillars of urban mobility - for example public transport, logistics, infrastructure, traffic management systems, car sharing and other mobility scenarios in a smart community.

One of the focal points of DIN SPEC 91367 is sector-wide integration (or interoperability) for the use of existing (IoT) infrastructures in the urban environment. This promotes sustainable community development in terms of ICT by using and further developing existing communication and sensor architectures. Therefore, DIN SPEC 91367 builds on the results of DIN SPEC 91357 and reinforces the structuring, interoperability, and modular extensibility of the urban data space.

DIN SPEC 91367 is aimed at municipalities, commercial transport companies, mobility service providers and suppliers, and local public transport, among others. It also includes data licensing models and properties (for example, data formats and data quality) that enable the economic development of the digitization of mobility.

6. Decide how to use your UDP

In the target and implementation concept, the city of Leipzig defined possible application areas / use cases, one of which was elaborated during the EfficienCE project.

Use cases and areas of application

As a central part of the future digital infrastructure of the city of Leipzig, the UDP-L is to be used for a variety of applications.

The term application area describes the domain-specific area within which the software solutions are created that access the data of the UDP. The definition of the Leipzig Urban Data Space already explicitly mentions energy, mobility, environment and health. In the following, further application areas are listed that also require solutions to access the data of the Urban Data Platform.

Use cases are target descriptions for individual solutions or solution modules that are to be supported by an UDP. They describe which functionality is to be provided with the help of which data. Currently, such use cases are mostly described in terms of agile development with the help of so-called user stories, which are then used as the basis for technical implementation.

Table 2: Typical application areas of an UDP

Area of application	Description
	(**E-Government**) Projects and measures aimed at optimising specialised tasks and processes within the administration as well as supporting communication and interaction with citizens/businesses or making access to services as convenient as possible.
	**Mobility**: Regional intermediation platforms for different target groups (professionals, families, pensioners, ...) to optimally coordinate their journeys with each other, e.g. through car-sharing and taxi apps. Projects for intelligent traffic control (e.g. parking space management and support in finding a parking space), environmentally friendly driving offers and multimodality up to (partially) autonomous driving as well as research into innovative mobility concepts for airspace and AI-based mobility.
	**Energy**: Intelligent systems for the collection and processing of generation, distribution and consumption data. Optimisation of energy management through smart technologies in neighbourhoods and regions. Intelligent coordination between energy generation and consumption as well as across sectors (sector coupling). Creation and implementation of smart energy solutions in residential, commercial or public buildings. See SPARCS project. Swarm power plants. Blockchain, energy transfers;

Umwelt	**Environment:** Digital solutions, e.g. for air and noise measurement and water quality through the use of sensor technology. Optimisation of regional material flows, intelligent waste disposal in the region and recycling measures, such as current air quality, groundwater levels, heat islands (KLIPS project), climate monitoring, networking with traffic data.

Currently, in the relevant literature, for example in the so-called DIN SPEC standards of the 913x7 series, the areas of mobility, energy, construction and environment are mentioned as central application areas for an urban data platform.

Relevant in the context of the EfficienCE project is the use of the UDP to process overarching use cases, such as the sector coupling of energy and mobility or the inclusion of environmental data.

Use case "Environmental Atlas Leipzig”

A collection of all environmental topics relevant to Leipzig. The environmental atlas could serve as a showcase to the outside world and inform the urban society about the most important environmental topics of the city, including editorial contributions.

Use case "E-charging points”

"The occupancy and expected releases of the e-charging columns are visualised. A notification service can be triggered via the application."

Use case "Traffic management”

In the context of traffic management for Leipzig, it is not only the data on the volume of traffic and the traffic situation within the city limits that is important, but also the data on the surrounding main traffic arteries that is relevant.

The aim of the **eULTIMATE** project was to develop a decision support system that designs the optimal charging system for a given city and quantifies the impact of the electric service on bus agencies and other stakeholders. During the project, datasets taken from the telemetric system of buses have been analyzed in Barcelona, Badalona, Lisbon, Decin, Zalaegerszeg and Kradec Kralove. Algorithms were developed to calculate the mean energy consumption of battery electric buses in real operation.

Link: https://www.eiturbanmobility.eu/projects/eultimate

Kruch railway innovations *facilitates* ***“digital twinning”*** of transport networks combining data and intelligence for all applications based on sensors, public information and other existing data, such as fleet data, infrastructure, passenger, energy, charging, battery monitoring, road and traffic, filling status, eco-driving and driver support as well as communication with traffic, e.g., V2X data. On this basis, vehicle defects, traction energy (incl. braking, recuperated) and heating and cooling energy consumption are tracked, as well as battery performance and driving behavior. Through simulation of energy-flows and display of voltage behavior along lines connection and charging planning is facilitated. Link: KRUCH | Railway Innovations

Figure 14: Good practices: data-based energy-efficient PT infrastructure planning and monitoring

7. Recommendations specifically for Leipzig UDP implementation and testing

In the Target and Implementation Concept of the UDP Leipzig, specific recommendations were made:

1) The UDP-L should meet all the necessary capabilities of categories "3" (data management and analysis), "5" (generic capabilities to support urban applications), "7" (interaction and communication) and "8" (privacy and sovereignty capabilities) of an open urban platform according to DIN SPEC 91357.

2) The UDP-L should be built as a system-of-systems on top of the existing systems GDI-L, SWL IoT Platform and Open Data Portal by using the IoT Platform for the capabilities of categories "0 - 2" (field components, communication, device management and georeferencing), the GDI-L as well as the Open Data Portal should provide the basic data as part of the capabilities of category "7" (interaction and communication).

3) The UDP-L should enable scalable, real-time data processing to refine the raw data of the IoT platform and be used for AI algorithms for real-time-based forecasting of, for example, mobility, traffic, or energy needs.

4) The UDP-L should pre-process raw data in such a way that data users can also make sense of the resulting information as part of their decision-making processes.

5) Establishment of the UDP-L as an independent city-wide IT system that takes over the orchestration between the systems within the city administration and the IoT platform of SWL and makes the data of the Leipzig Urban Data Space available to third parties - among other things via the Open Data Portal.

6) The UDP-L should enable scalable and cost-efficient connection of third-party systems to allow continuous development and expansion.

7) The UDP-L should have a (possibly federated) data catalog documenting the available data, its location, and access rights.

8) Because of its citywide connectivity and orchestration function, the UDP-L requires specific UDP governance.

9) To reduce complexity while promoting subject-specific acceptance of the UDP as a connecting IT system, multi-perspective view models (e.g., data, applications, technology, effects) should also be used in the specific development of UDP governance.

10) The core of UDP governance is the development of a catalog of the facts to be regulated ("rule inventory") and their location in a system of corresponding operational and strategic responsibilities (actors).

11) Existing structures are to be used largely for the organizational anchoring of the cooperation and control processes required for the UDP.

The external expert team recommended that the City of Leipzig, together with the L-Group, build on the detailed concept to operationalize the results that are already available or have been additionally developed with the perspective of a UDP-L as an independent connecting IT system in a system of systems.

- Setting up a test lab for a UDP-L in accordance with the target architecture in the sense of a system of systems as an integrated infrastructure in accordance with DIN SPEC 91357. Such a test installation should be set up within eight to twelve weeks and validated over six months as a pilot with the aid of selected use cases.
- Elaboration of four to five use cases that illustrate the added value of a UDP-L, i.e., that particularly benefit from the above target architecture. Based on the presented and discussed

use cases, those should be selected that can be (prototypically) realized within three to six months to be used for the pilot. In particular, those use cases should be selected that demonstrate the special challenges to real-time capability. The team of experts therefore recommends that the areas of traffic and environment be examined in greater depth, as was shown in the example of Darmstadt.

- Establishing a Data/UDP-L working group as a sub-working group of the "Digitization and Change Management" steering committee with the aim of developing a data strategy for the city group and a steering structure (governance) for the UDP-L. The data strategy and governance structure should be developed in parallel with the establishment of the test lab. In doing so, the findings from the pilot will be used for validation.
- Elaborate and establish a sustainable operating model for the UDP-L that meets the growing challenges of flexibility and dynamism, such as those posed by the new world of IoT devices. The IoT platform of the L-Group should be the model and starting point for this. The operator model will be developed in parallel with the establishment of the test lab based on the operational requirements and will serve as a decision-making basis for the implementation of the productive phase.

9. EfficienCE use case and lessons learnt for data-based planning

The City of Leipzig and the Leipzig PTO, LVB, collaborated in an explorative approach in the analysis of large data amounts collected via on-board computers and Raspberry PI sensors in six trams, linking them with other data sources (e.g., mobility, traffic space design and energy data), and generating insights how the energy consumption through the tram infrastructure can be reduced[4]. Using the IT infrastructure provided by the municipal department for geodata infrastructure developed and maintained by their internal IT company, a dashboard was produced to analyse the data sets and to understand how the findings can be used to reduce energy consumption. Also, how the findings can be sustainably implemented in the monitoring and process control architecture.

Based on descriptive statistics applied to the large data sets, statements could be made on the energy consumption of specific rail sections within supplying electrical substations, as well as on journey time performance, rail infrastructure and their impact on the tram performance. To validate the results, explorative data science methods were applied to the data sets, and recommendations for energy monitoring and infrastructure maintenance, and the harmonisation of data sources and flows for the tram and IT infrastructure were made. Based on these recommendations, LVB now plans to further develop the use case into a predictive tram infrastructure maintenance application. The city of Leipzig uses them to further develop methods for digital transport planning in a follow-up project as the UDP progresses into a digital twin. [5]

The main organisational obstacle was to get all needed stakeholders on board to support and commit to the project, which was overcome by the creation of a jour fixe and data workshops between representatives from the municipal administration and the PTO.

Main data-based obstacle was missing transparency about data: existing data and how they are structured, missing or incomplete data. The project partners learnt that a permanent transparent data catalogue should be available to keep an overview over existing data.

[4] For more detailed description please refer to D.T1.2.3 UDP use case Leipzig & LVB and O.T1.2.1 Output factsheet Leipzig & LVB UDP use case

[5] CUT project

Instead of manual data transaction (with the help of USB sticks), future automated data delivery is envisaged, to enable automation of digital planning processes.

Both partners find they gained added value to increase energy-efficiency and sustainability from the use case. For LVB, the achieved overview of the conditions of the track network supports enhanced decision-taking for construction planning, more efficient use of staff and better working conditions through better maintenance of assets, thus avoiding subsequent faults and reducing costs through optimised computer-based planning and minimally invasive interventions. The City of Leipzig uses the collected data for its air quality dashboard, and as an practice example for monitoring dynamic data based on KPI.

As a takeaway from the use case, the partners will now implement:

- Standardised monitoring of tram energy consumption
- Harmonisation of hardware data sources and data flows and its operative implementation (tram & IT-structure)
- Monitoring of actual energy consumption of rail sections within the supplying electrical substations to optimise spending
- Monitoring of rail infrastructure and its impact on tram performance to deduce the magnitude of its dependence on individual transport, traffic area design as well as weather etc

The partners also underline:

- cities and PTO who want to start with data-based planning should engage in inter-municipal exchanges in specialist formats, where statisticians and planners informally show each other software, data, and what interaction between data and their work is possible.
- data-based monitoring is not an end in itself, but the added value behind a monitoring activity should always be clear (what are our questions, can we answer them based on the data?).
- to not simply digitise processes, but to also optimise these processes while digitising.
- data-based decision-taking should not solely rely on algorithms, which can only select where humans should have a closer look to make decisions. Humans should, thus, remain the decision-making experts based on their experience.
- it is very important to always keep a good understanding of the data quality, and the structure of applied algorithms.

Figure 15: Data sources for the EfficienCE use case

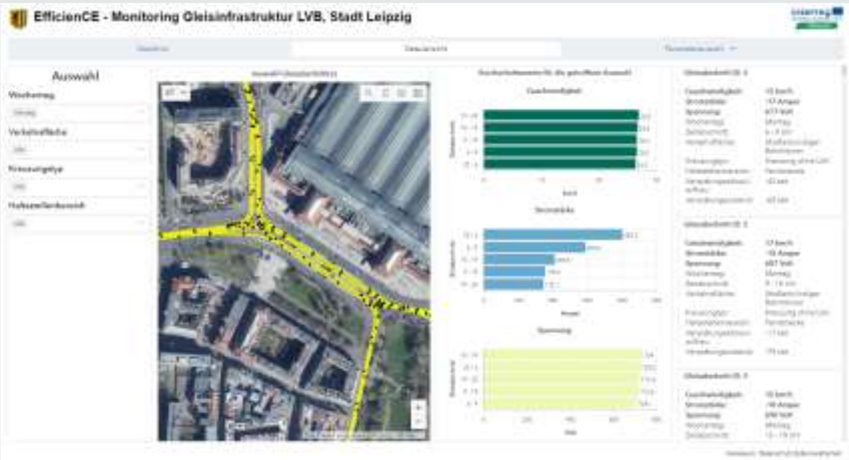

Figure 16: Dashboard to monitor the track infrastructure in Leipzig

10. Explore other UDP case studies

Case studies from other German Cities

Hamburg

With the Urban Data Platform Hamburg (HH_UDP) and a comprehensive digital strategy (Hamburg 2020), the Free and Hanseatic City of Hamburg is pursuing a path of consistent and self-determined innovation. The platform is not an isolated solution, but follows, together with many other European cities, the Urban Data Platform Initiative of the European Innovation Partnership on Smart Cities and Communities, which has been continued under the name Smart City Marketplace since 2021. In the age of exploding data volumes, the city of Hamburg sees central control for the consolidation of data in the digital city as an instrument that helps to reduce and optimise the costs of data management. This central coordination is also intended to centrally check and improve the quality of the data.

The foundation of the platform is based on four steps:

1. definition of a Digital City Hamburg strategy

2. setting up an urban data platform as the technical heart of the platform

3. collect and connect data

4. create added value for the city (society).

The Urban Platform Hamburg can be seen as a system of systems in which the city's data is brought together and made available interoperably for a wide range of applications via standardised interfaces.

The modernisation of urban transport in Hamburg with a view to the goals of Agenda 2030 is cited as an ideal application example of an Urban Data Platform. In order to achieve these goals, a non-discriminatory provision of dynamic traffic data by means of open, standardised, event-based interfaces is required. In this way, Hamburg is pursuing similar goals as the city of Darmstadt. In Hamburg, there are already various real-time data from sensors installed in counting loops, traffic lights, environmental measuring stations and car parks. In addition, thousands of new sensor data streams will be added in the future through various Hamburg projects on intelligent traffic systems such as an automated traffic volume recording, a cycling traffic counting network, a digital warning beacon at road construction sites and a traffic light forecasting service.

Applications of the Hamburg platform from the transport & traffic sector include the traffic portal, noise maps on road traffic or information on the topic of electromobility with information on the charging infrastructure. Within the transport portal (see Fig. 7), extensive information can be found on the individual modes of public transport (bus, rail, ferries), cycling and walking, parking options and occupancy, traffic situation or road works.

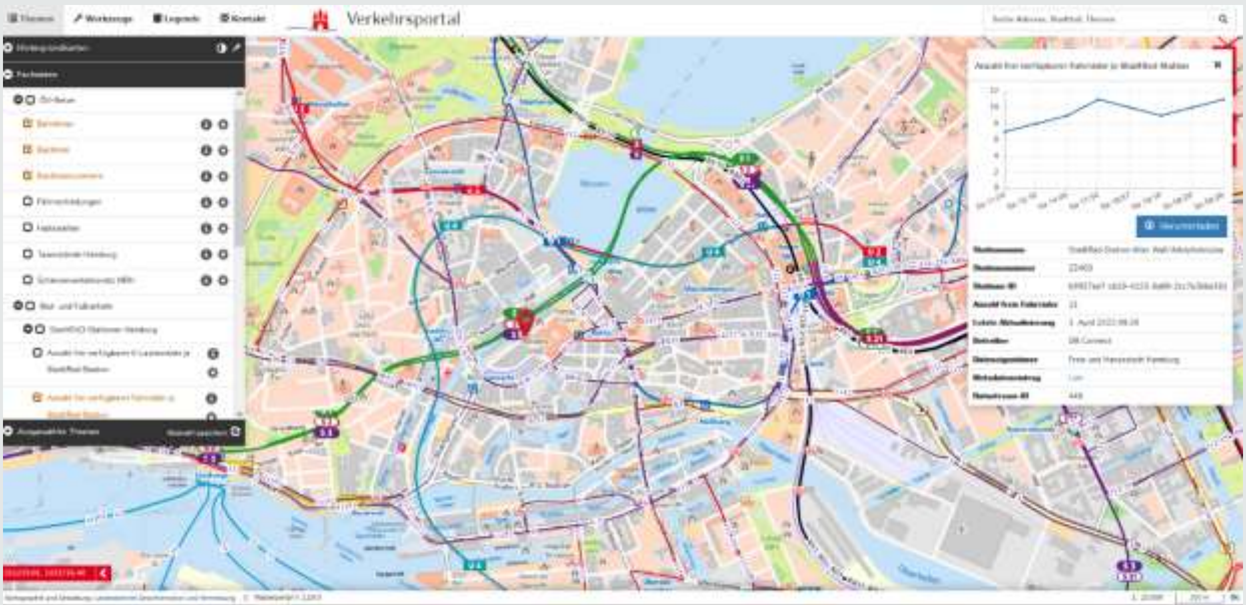

Figure 17: Screenshot Transport and Traffic Portal Hamburg[6]

Köln

Cologne approached the topic of urban data platforms in 2014 through a Horizon 2020 project. In the GrowSmarter project (2015 - 2019), various topics from the areas of energy efficiency, mobility and

[6] https://geoportal-hamburg.de/verkehrsportal/

digitalisation were worked on together with Barcelona and Stockholm. This includes the development of an urban data platform, in which the various measures such as traffic situation and parking situation on the one hand and data from mobility stations as well as environmental and air quality data on the other hand are visualised as an indicator set for climate protection-relevant measures. The project area for GrowSmarter, the Stegerwaldsiedlung in the Mühlheim district, was awarded the title of "climate protection settlement" by the EnergyAgency of North Rhine-Westphalia because energy consumption was successfully reduced.

The GrowSmarter project tested technologies and services that will shape environmentally conscious urban life in the future. The motto of SmartCity Cologne is: Implementing the energy transition together. The architecture of the Urban Data Platform from the GrowSmarter project can be found in figure 8. Three system layers were considered. The data sources (analogous to the category "0 - record, measure") were provided by the city of Cologne, the municipal utility group subsidiaries KVB (transport companies) and RheinEnergie (energy supplier) as well as private companies (Cambio and Ampido). Thus, different data suppliers from different environments could be connected. In the data management and analysis layer, data harmonisation and processing were carried out and in the APPs and data platform, the interaction and communication capabilities were tested.

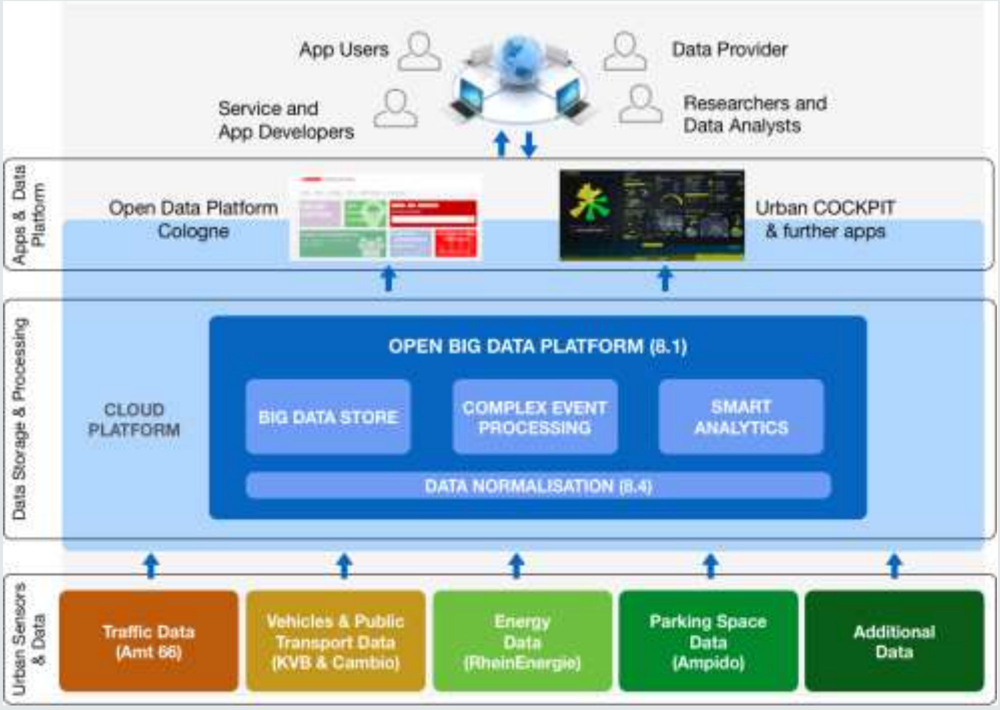

Figure 18: High Level Architecture of GrowSmarter UDP Köln[7]

An important insight from the GrowSmarter project was the importance of data in the implementation of the smart city strategy and the achievement of the ambitious (climate protection) goals. Therefore, the municipal utility group under the leadership of RheinEnergie and the city of Cologne are working intensively on the development of a corresponding infrastructure. Both in the GrowSmarter project and in the "Climate Street" project, a number of use cases in the application areas of energy, construction, mobility and environment were set up and validated. This also showed that a lot of convincing still needs to be done, especially on the question of willingness to make data available to third parties. For example, mobility service providers have been concerned about providing the availability of their fleet

[7] https://grow-smarter.eu/fileadmin/editor-upload/12Solutions/Factsheets/Integrated_infrastructures/S8.1_F32_GrowSmarter_Urban_TRAFFIC_Cologne.pdf

in a geo-referenced form, as potential competitors could use this to make important deductions about "attractive locations". Tenants of the Stegerwaldsiedlung were concerned that the refurbishment would not only pursue energy goals but also increase property values (so-called luxury refurbishment), which could lead to a disproportionate increase in rents.

Conclusion

The managerial approach was derived from the EfficienCE use case for energy-efficient PT infrastructure planning by the city of Leipzig and LVB, and reviewed by the PTOs Wiener Linien (AT), ATB Bergamo (IT). While the managerial approach is implemented in Leipzig through the adoption of the EfficienCE use case and its further exploitation in digital transport planning and development into a predictive maintenance service in follow-up projects, the transnational added value is also high. UDPs are very innovative, especially in central Europe, and there is a high need for relatable information and comprehensive guidance how to step-by-step implement such an instrument, and how to use it for planning - especially across transport authorities and public transport operators. The managerial approach for data-based planning can be used as a starting point and guidance for such a process.

References

EfficienCE deliverables (to be found on the EfficienCE website)

- **D.T1.2.3 Action Plan for energy-efficient PT infrastructure deployment** (UDP use case City of Leipzig & LVB)
- **O.T1.2.1 Output factsheet - Action Plan for energy-efficient PT infrastructure deployment** (City of Leipzig & LVB UDP use case)

Weblinks

RAIM-Architektur

Study "Urban Data Spaces" by Fraunhofer FOKUS (https://www.fokus.fraunhofer.de/de/fokus/presse/urbaneDatenraeume-Studie-Datenmanagement_2018_06)

CUT project

https://geoportal-hamburg.de/verkehrsportal/

https://grow-smarter.eu/fileadmin/editor-upload/12Solutions/Factsheets/Integrated_infrastructures/S8.1_F32_GrowSmarter_Urban_TRAFFIC_Cologne.pdf