URBAN LOGISTICS AS AN ON-DEMAND SERVICE

Modular System Architecture

ULaaDS D3.4: ULaaDS: technology solutions, concepts and tools (includes modular system architecture, final version)

Date: 19/09/2023

Author(s): Müller, Philipp

Co-author(s):

The ULaaDS project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 861833. ULaaDS is a project under the CIVITAS Initiative.

CIVITAS Sustainable and smart mobility for all

THE CIVITAS INITIATIVE IS CO-FUNDED BY THE EUROPEAN UNION

Deliverable details

Project acronym	Project title
ULaaDS	Urban Logistics as an on-Demand Service

WP	Deliverable title
3	D 3.4 ULaaDS: technology solutions, concepts and tools (includes modular system architecture, final version)

Document history

Version	Date	Author(s)	Status*	Dissemination level**
1.0	28.06.2023	Philipp Müller	Draft	PU
1.1	19.09.2023	Philipp Müller	Final	PU

*Status: Draft, Final, Approved, Submitted (to European Commission).

Dissemination Level: **PU: Public; **CO**: Confidential, only for members of the consortium (including the Commission Services); **EU-RES** Classified Information - restraint UE; **EU-CON**: Classified Information - confidential UE; **EU-SEC**: Classified Information - secret UE

Contractual delivery date	Actual delivery date	Deliverable type*
31.05.2023	28.06.2023	R

*Deliverable type: **R**: Document, report; **DEM**: Demonstrator, pilot, prototype; **DEC**: Websites, patent fillings, videos, etc; **OTHER**; **ETHICS**: Ethics requirement; **ORDP**: Open Research Data Pilot.

Project abstract

ULaaDS sets out to offer a new approach to system innovation in urban logistics. Its vision is to develop sustainable and liveable cities through re-localisation of logistics activities and re-configuration of freight flows at different scales. Specifically, ULaaDS will use a combination of innovative technology solutions (vehicles, equipment and infrastructure), new schemes for horizontal collaboration (driven by the sharing economy) and policy measures and interventions as catalysers of a systemic change in urban and peri-urban service infrastructure. This aims to support cities in the path of integrating sustainable and cooperative logistics systems into their sustainable urban mobility plans (SUMPs). ULaaDS will deliver a novel framework to support urban logistics planning aligning industry, market and government needs, following an intensive multi-stakeholder collaboration process. This will create favourable conditions for the private sector to adopt sustainable principles for urban logistics, while enhancing cities' adaptive capacity to respond to rapidly changing needs. The project findings will be translated into open decision support tools and guidelines.

A consortium led by three municipalities (pilot cities) committed to zero emissions city logistics (Bremen, Mechelen, Groningen) has joined forces with logistics stakeholders, both established and newcomers, as well as leading academic institutions in EU to accelerate the deployment of novel, feasible, shared and ZE solutions addressing major upcoming challenges generated by the rising on-demand economy in future urban logistics. Since large-scale replication and transferability of results is one of the cornerstones of the project, ULaaDS also involves four satellite cities (Rome, Edinburgh, Alba Iulia and Bergen) which will also apply the novel toolkit created in ULaaDS, as well as the overall project methodology to co-create additional ULaaDS solutions relevant to their cities as well as outlines for potential research trials. ULaaDS is a project part of ETP ALICE Liaison program.

Keywords

Urban logistics, sustainability, modular system architecture, data

Copyright statement

Table of contents

List of figures

1. Introduction

In today's interconnected world of logistics, the exchange of data becomes increasingly (more) important for both private companies and public municipalities. Private companies often possess valuable data and insights regarding their own processes that can contribute to the holistic efficiency of urban mobility and logistics, while municipalities have access to data that can benefit businesses in various ways.

Private companies, driven by their expertise and access to advanced technologies, possess valuable data and insights that can enhance public services and contribute to the well-being of the community. For instance, a transportation company may have real-time data on traffic patterns, allowing a municipality to optimize traffic flow and improve public transportation routes. On the other hand, public municipalities possess a vast array of data that can be of value to private companies. This data, which includes demographic information, public infrastructure details, environmental data, and more, can help businesses make informed decisions, target their services effectively, and create products and solutions tailored to the needs of the community.

However, for this data exchange to be successful, it requires a robust system architecture that addresses the unique challenges and considerations involved in the collaboration between private companies and public municipalities. A well-designed system architecture provides the foundation for efficient and secure data exchange by addressing factors such as interoperability, scalability, reliability, security, and compliance.

This deliverable D 3.4 provides the final system architecture for the ULaaDS research trials. The reader, especially partners involved in data handling, shall be supported in the understanding of data and information flows as well as responsibilities within the project. Furthermore, this procedure shall foster the standardization and transparency of data processing within but also after the project. Therefore, the proposed system architecture aims to be a blueprint that can be used for data and communication flow in the field of urban logistics and future developments in which many stakeholders interact and may exchange data.

In this deliverable, especially the integration of the research trials is focused as they represent an important data source in the project with many partners involved. Therefore, the following chapter focusses first on the interrelationships with the other work packages (WPs) which provide input for this deliverable. Second, benefits but also anticipated challenges of a modular system architecture for logistics companies and municipalities are outlined. Next, the preparatory work to elaborate the system architecture during the trial set-up is presented. The fourth chapter is about the implementation of the system architecture in ULaaDS and examines the data exchange in the different research trials during their execution. Last, derivations regarding future system architectures and data exchange procedures from the lessons learned in ULaaDS are formulated.

2. Interrelationships of WPs

This deliverable builds upon aspects and (provisional) content from different WPs and their deliverables. Content that was included in this document are inter alia:

- **WP 1:** Data requirements and how the data will be treated and secured within ULaaDS, which is presented in D 1.3 ("Data Management Plan" (DMP)), is key also for the presented system architecture. It is a guiding document to respect the General Data Protection Regulation (GDPR) as well as the data sovereignty of each project member contributing data.
- **WP 2:** Due to the fact, that not all data is of quantitative nature, an integration of the local urban freight fora and other formats (like interviews) is necessary to gain more (qualitative) insights into the ULaaDS trials. Insights gained at these events must also be adequately preserved.
- **WP 3:** Inter alia technical aspects (e. g., vehicles, hubs, IT) to adapt urban freight delivery systems to the requirements of on-demand and zero emission (ZE) logistics solutions are described in D 3.1 (Benchmarking business/operating models and best practices). This knowledge base will be used during the trial evaluation to discuss with respective partners the (data-related) possibilities to foster the interoperability among transport modes and systems in terms of supply chain coordination, load unit optimization, communication and data exchange interfaces if possible.
- **WP 4:** D 4.1 ("Pre-trial set-up") is about giving guidance to the lighthouse cities during the implementation, execution and evaluation of the trials. Its goal is to ensure that trials are implemented adequately and on time. Allowing for analysis and comparison of results, the different trials must follow a unified methodology. Partner input and data is and will be directly fed into the system architecture to monitor the status quo as well as deviations to the initial planning.
- **WP 5:** D 5.1 ("Framework, methodology and KPI identification") presents the framework for the impact assessment of the ULaaDS trials. The framework identifies and defines areas of impact, objectives and indicators for the trials. To evaluate the trials at a later point, conserving baseline and after-trial-implementation data in a sound data base is essential.

3. Modular system architecture

As shown above, several WPs are related with D 3.4. Following, the elaboration of the system architecture will be described. The modular system architecture aims to support the understanding of data and information flows between partners as well as responsibilities within the ULaaDS project and urban logistics as a whole.

Especially, the integration of the research trials is focused as they represent an important data source in ULaaDS with many partners involved. By elaborating a modular system architecture, providing background information of the research trials and showing their current insights, this procedure shall foster the understanding of benefits, challenges and derivations of data handling faced in this project and for future developments in this field.

Following, general benefits of system architectures for logistics companies and municipalities are outlined (see Chapter 3.1). Second, anticipated challenges in the field of urban logistics regarding data exchange are examined (see Chapter 3.2), while last, the preparatory work for setting up the system architecture in ULaaDS is presented (see Chapter 3.3).

3.1 Benefits

3.1.1 Logistics Companies

A data system architecture can play a significant role in helping logistics companies optimize their operations, enhance efficiency, and improve decision-making processes. Following, different building blocks of system architectures and related technologies show up how logistics companies can benefit from these:

[1] **Real-time Logistical Visibility:** A well-designed data system architecture can enable real-time tracking and visibility of shipments and assets. By integrating various data sources such as GPS, RFID, and sensors, logistics companies can monitor the movement, location, and condition of goods throughout the supply chain. This visibility can improve inventory management, delivery tracking, and also customer service.

[2] **Demand Forecasting and Planning:** A data system architecture can integrate historical and real-time data to enable accurate demand forecasting and planning. By analysing factors such as customer orders, historical sales data, market trends, and external factors, logistics companies can optimize their inventory levels, allocate resources effectively, and streamline their supply chain operations to meet customer demand while minimizing costs and stockouts.

[3] **Vehicle Routing and Optimization:** Through data system architecture, logistics companies can leverage algorithms and optimization techniques to determine the most efficient routes for their vehicles. By considering factors like traffic conditions, delivery priorities, vehicle capacities, and fuel costs, the architecture can generate optimized delivery schedules, reduce fuel consumption, improve on-time performance, and minimize transportation costs.

[4] **Warehouse Management:** Data system architecture can support effective warehouse management by providing real-time visibility into inventory levels, location tracking of goods, and automated workflows. Integration with technologies such as barcode scanning, RFID, and automated picking systems enables accurate inventory management, efficient order fulfilment, and streamlined warehouse operations.

[5] **Supplier and Carrier Collaboration:** A data system architecture can facilitate collaboration and information exchange with suppliers and carriers. By establishing electronic data interchange (EDI) capabilities, application programming interfaces (APIs), or web portals, logistics companies can seamlessly share information such as purchase orders, shipment statuses, and invoices. This integration enhances communication, reduces manual data entry, and improves efficiency throughout the supply chain.

[6] **Performance Monitoring and Analytics:** A data system architecture enables the collection, storage, and analysis of operational data. Through data analytics, logistics companies can gain insights into key performance indicators (KPIs) such as delivery times, order accuracy, inventory turnover, and transportation costs. These insights help identify bottlenecks, inefficiencies, and areas for improvement, enabling data-driven decision-making and continuous process optimization.

Overall, a well-designed data system architecture empowers logistics companies with timely, accurate, and actionable information. By harnessing the power of data, logistics companies can optimize their operations, enhance customer service, reduce costs, and stay competitive in a rapidly evolving industry.

3.1.2 Municipalities

On the one hand, municipalities often possess meaningful data themselves that can improve the work of third parties. On the other hand, access to data from logistics companies can provide municipalities with several benefits, enabling them to enhance public services, improve urban planning, and optimize resource allocation.

[1] **Traffic Management and Urban Planning: Logistics** data can provide municipalities with valuable insights into traffic patterns, congestion hotspots, and transportation flows. By getting access to this data, municipalities can make better informed decisions regarding traffic management, road infrastructure improvements, and urban planning. This can help optimize traffic flow, reduce congestion, and improve overall transportation efficiency within the city.

[2] **Sustainable Urban Development:** Access to logistics data allows municipalities to assess the environmental impact of transportation activities within the city. By understanding the volume of freight movement, delivery routes, and associated emissions, municipalities can develop strategies for sustainable urban development. This includes promoting eco-friendly transportation modes, optimizing delivery schedules, and implementing environmentally conscious policies to reduce carbon footprint and improve air quality.

[3] **Infrastructure Planning and Maintenance:** Logistics data provides municipalities with insights into the demand for transportation infrastructure, such as roads, bridges, and public transit systems. By analysing logistics data and combining them with other data sources, municipalities can identify areas of high demand, plan infrastructure expansion or improvement projects, and allocate resources effectively. This helps ensure that transportation infrastructure meets the needs of the growing population and facilitates economic development.

[4] **Economic Development and Investment:** Access to logistics data enables municipalities to attract businesses, stimulate economic growth, and optimize investment strategies. By understanding trade flows, supply chain dynamics, and logistics requirements, municipalities can identify potential areas for economic development and plan targeted investment initiatives. This can include identifying logistics hubs, optimizing trade routes, and providing tailored support to logistics companies, thereby attracting investment and fostering job creation.

[5] **Data-Informed Decision Making:** Access to logistics data empowers municipalities with valuable insights for evidence-based decision making. By analysing data on transportation patterns, supply chain flows, and logistical requirements, municipalities can make informed policy decisions, prioritize investments, and optimize the allocation of resources. This data-driven approach leads to more efficient and effective governance, improving the overall quality of public services provided by the municipality.

Overall, access to logistics data provides municipalities with a wealth of information to improve transportation infrastructure, optimize urban planning, stimulate economic development, and make data-informed decisions. By leveraging this data, municipalities can create smarter, more sustainable, and liveable cities for their residents. Furthermore, improvements for the logistics companies as transportation network users can be derived.

3.2 Anticipated Challenges

Nevertheless, when exchanging data between different entities like municipalities and/or private actors, several challenges and problems may arise. These can impact the efficiency, reliability, and security of the data exchange process.

[1] **Data Incompatibility:** Entities may use different data formats, schemas, or conventions, making it challenging to exchange data seamlessly. Incompatible data structures or representations can lead to data loss, misinterpretation, or errors during the exchange process.

[2] **Interoperability Issues**: Lack of interoperability between systems and applications can hinder data exchange. Incompatible interfaces, protocols, or APIs can create barriers and require complex integration efforts. Inconsistent or undocumented interfaces can further complicate the exchange process.

[3] **Security Risks:** Data exchange involves the risk of unauthorized access, data breaches, or data leakage. Insufficient security measures, weak authentication mechanisms, or inadequate data protection practices can expose sensitive information to malicious actors.

[4] **Data Quality and Integrity:** Ensuring the accuracy, completeness, and integrity of exchanged data can be a challenge. Inconsistent data validation, data entry errors, or data corruption during transmission can lead to unreliable or inaccurate information.

[5] **Dependency on Legacy Systems:** Legacy systems that are outdated or have limited capabilities may struggle to integrate with modern data exchange requirements. Compatibility issues, limited functionality, or lack of support can pose challenges in exchanging data with entities using newer technologies.

[6] **Data Governance and Compliance:** Ensuring compliance with data privacy regulations, industry standards, and legal requirements can be a complex task. Data sharing agreements, consent management, and adherence to data protection regulations like GDPR need to be carefully addressed.

[7] **Cultural and Organizational Differences:** Entities from different organizations or sectors may have varying data management practices, policies, or governance structures. Misaligned expectations, differences in data sharing culture, or conflicting priorities can hinder effective data exchange.

[8] **Lack of Trust and Collaboration:** Establishing trust and fostering collaboration between entities is crucial for successful data exchange. Lack of transparency, concerns about data misuse, or a lack of established relationships and shared goals can hinder cooperation and hinder the exchange of data.

Addressing these problems requires careful planning, effective communication, and the implementation of appropriate technical, organizational, and governance measures. By proactively identifying and mitigating these challenges, entities can establish a more seamless and secure data exchange environment.

3.3 Preparatory Work

As examined in the previous chapter, establishing a system architecture can have benefits for logistics companies and municipalities. Furthermore, the exchange of data between them can be insightful for both parties. Nevertheless, it was also shown that challenges can arise due to this topic.

To address these topics, ULaaDS proposed an approach of data-related work in advance and parallel to the trial execution. In the following sub-chapters, this approach is outlined. The elaboration steps of the modular system architecture are shown in Figure 1. The modular system architecture can be found in the Appendix. The implementation of the system architecture in ULaaDS will be presented in Chapter 4.

Figure 1: Modular system architecture elaboration steps

3.3.1 Data Preparation

Data preparation was mainly conducted by the ULaaDS partners TOI due to their work in defining KPIs to evaluate the impacts of the ULaaDS trials. D 5.1 covers the framework for the impact assessment. It identifies areas of impact, objectives and indicators that should be addressed and measured within the trials. The areas of impact to be assessed in ULaaDS are:

- environment,
- land-use,
- traffic conditions,
- logistics efficiency,
- economic impacts,
- user experience and
- acceptance and awareness.

Their work from the beginning of 2021 represents the guiding document against which the trials should be measured to evaluate the trials in a standardized manner. If deviations occur, they must be documented to understand why they happened and to what extent they result in changes regarding the impact assessment.

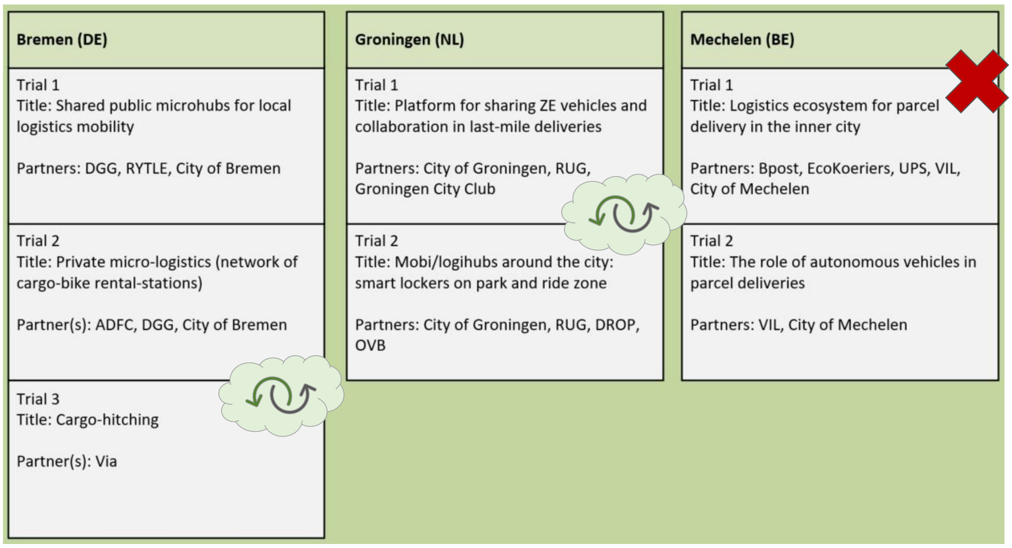
3.3.2 Data Input Sources and Formats

ULaaDS is conducting research trials for ZE, shared and crowdsourced on-demand delivery of goods to customers and businesses in the lighthouse cities of Bremen, Mechelen and Groningen. Schemes that are tested include containerised last-mile delivery, platforms for on-demand city logistics and integrated management of urban logistics, hubs for dual goods and passenger flows (Mobihubs) and shared vehicles (Cargo-hitching) (see Figure 2).

Bremen (DE)	Groningen (NL)	Mechelen (BE)
Trial 1 Title: Shared public microhubs for local logistics mobility Partners: DGG, RYTLE, City of Bremen	Trial 1 Title: Platform for sharing ZE vehicles and collaboration in last-mile deliveries Partners: City of Groningen, RUG, Groningen City Club	Trial 1 Title: Logistics ecosystem for parcel delivery in the inner city Partners: Bpost, EcoKoeriers, UPS, VIL, City of Mechelen
Trial 2 Title: Private micro-logistics (network of cargo-bike rental-stations) Partner(s): ADFC, DGG, City of Bremen	Trial 2 Title: Mobi/logihubs around the city: smart lockers on park and ride zone Partners: City of Groningen, RUG, DROP, OVB	Trial 2 Title: The role of autonomous vehicles in parcel deliveries Partners: VIL, City of Mechelen
Trial 3 Title: Cargo-hitching Partner(s): Via		

Figure 2: Preliminary trials and involved partners in the lighthouse cities (10/21)

During regular bilateral meetings with the respective partners involved, the implementation progress of the trials and their current status, also regarding data generated, was asked for. Figure 3 illustrates the development of the preliminary defined trials. As illustrated, there were some changes in the preparation period of the different trials in the three lighthouse cities, a common feature of research and innovation projects. One of the trials did not result in physical deployment due to different reasons while the circumstances of three others changed over time. The background information are outlined in Chapter 4 and also how these affected the implementation of the system architecture.



Bremen (DE)	Groningen (NL)	Mechelen (BE)
Trial 1 Title: Shared public microhubs for local logistics mobility Partners: DGG, RYTLE, City of Bremen	Trial 1 Title: Platform for sharing ZE vehicles and collaboration in last-mile deliveries Partners: City of Groningen, RUG, Groningen City Club	Trial 1 Title: Logistics ecosystem for parcel delivery in the inner city Partners: Bpost, EcoKoeriers, UPS, VIL, City of Mechelen
Trial 2 Title: Private micro-logistics (network of cargo-bike rental-stations) Partner(s): ADFC, DGG, City of Bremen	Trial 2 Title: Mobi/logihubs around the city: smart lockers on park and ride zone Partners: City of Groningen, RUG, DROP, OVB	Trial 2 Title: The role of autonomous vehicles in parcel deliveries Partners: VIL, City of Mechelen
Trial 3 Title: Cargo-hitching Partner(s): Via		

Figure 3: Final trials and involved partners in the lighthouse cities (06/23)

During the project period, the foreseen data formats of structured and unstructured data were confirmed. Structured data are mainly machine-readable files. A common format for this type of file is CSV. Feedback from the research trials is primarily in this format or in Excel spreadsheets due to mainly quantitative KPI definitions provided by the ULaaDS partner TOI and generated in the trials.

As presented, also other data sources are relevant to understand and evaluate the impacts of the ULaaDS trials. One main data source are the local fora of WP 2. It was foreseen that mainly unstructured data will be generated. Unstructured data covers mainly formats like Word documents, PowerPoint Presentations, PDFs and illustrations. These documents will be mainly provided by the project partner IFZ.

3.3.3 Data processing

Since in ULaaDS several solutions are piloted and evaluated, it is necessary to define actions when working with data. Therefore, several data handling options were defined in advance to the data collection, processing, and evaluation (see Figure 4).

Figure 4: Data handling options of ULaaDS system architecture

These options were installed to improve data quality provided by data owners, to foster understanding of the options' necessity and define measures to handle data gaps. As presented in Figure 4, often **decisions** must be taken as a first step (e. g. "Has a specific research trial provided the promised data (on time)?"). These decisions lead to **actions** as the decisions can be fulfilled or not. In some cases, smaller changes can solve data handling obstacles (e. g. adjusting input data or changes regarding collection methods). Decisions and actions are also based on related documents that were produced in the project, like the DMP. Therefore, **references** to other ULaaDS documents are added to the system architecture to foster neutral decision-making processes.

Nevertheless, also in the first version of the system architecture, it was foreseen that that **escalations** may occur. In these cases, the project coordination must be informed as well as **open questions, responsibilities and permissions** be clarified (e. g. "Data not provided on time/in adequate quality" ➔ "What are the time/content tolerances for data transmission?"). For these reasons, the system architecture shows up an optimal way of **data and communication flows,** while offering deviations due to circumstances arising during the project period.

After receiving the third parties' data, they must be stored and processed in an adequate way and **definition and sources** as well as which **partners** are **involved** in certain steps have to be clear in order to align the work conducted within ULaaDS in an efficient way. The guiding document for data storing and processing is integrated by references to the DMP to work in line with the GDPR and remind every involved partner of his rights and duties.

3.3.4 Data Analytics

Data Analytics will be conducted in cooperation with the partners of WP 5 who are responsible for evaluating economic impacts, user experience acceptance and awareness (Miebach) as well as impacts on logistics and traffic efficiency, land use and the environment (TOI).

Furthermore, it will depend essentially on the willingness of the research trials' partners to contribute to the practical research trials data collection conducted in WP 4.

3.3.5 Data Information Exploitation Layer

The data information exploitation layer will be elaborated with focus on the "ULaaDS decision support toolbox" which will be designed in task T 6.4. Its focus is the integration of the project developments inter alia the solutions, measures, and impact assessment. The result of this task is the development of an application-oriented decision support toolbox for public authorities and industry players to generate pathways for on-demand and ZE urban logistics activities. Therefore, iterative feedback loops will be conducted to match the expectations of the decision support toolbox and the data-related possibilities.

At this point (06/23), the data collection has reached a lively level while not being finalised. Therefore, the impact assessment possibilities are being evaluated by the respective partners (especially Transportøkonomisk institutt (TOI), Miebach, Rijksuniversiteit Groningen (RUG), VIL and Fraunhofer Institute for Material Flow and Logistics (IML)) and its possible derivations for the toolbox are foreseen for the upcoming project period.

4. Implementation of System Architecture in ULaaDS

As presented in the previous chapter, the implementation of the system architecture proposed is closely linked to Task 4.5 which covers the data collection within ULaaDS. Iterative data collection from testbeds involves a continuous process of gathering information from the trial leaders, analysing the status quo, and refining whether the data input can be further improved regarding the goals of ULaaDS of inter alia impact assessment. The trials serve in ULaaDS as closed environments where the partners involved (like municipalities, private companies and researchers) can deploy and evaluate new concepts of sustainable urban logistics. Through iterative data collection, the aim is to derive valuable insights as well as use patterns that may occur over the time during the operation period of certain concepts. This iterative approach allows for the identification of potential issues, refining of parameters and validation of hypotheses made in advance to the implementation. Furthermore, this should also lead to informed decision- and policymaking to drive innovation and enhance the overall data-related cooperation of future experimental systems.

Following, the status quo of the different research trials is examined and mirrored against the implementation of the system architecture. The aim is to show up potentials of data-related collaboration within ULaaDS but also challenges that occurred. By this, ULaaDS can derive valuable insight for future projects in this field regarding data exchange structures between different stakeholders of sustainable urban logistics (see also Chapter 5).

4.1 Bremen (Germany)

4.1.1 Trial 1 - Shared public microhubs for local logistics mobility

The first ULaaDS trial in Bremen aimed on expanding the number of micro hubs and cargo bike freight transport which should lead to a decrease of lorry movement in the inner city. The focus was on palletized cargo and also parcels. Therefore, the city of Bremen wanted to test containerised urban last-mile delivery. Parcel and the palletized cargo are sorted according to the delivery zone already at the warehouse. Then, containers heading to the inner city will be delivered at micro hubs and collected by cargo bikes for the final stretch.

Due to an app, the involved partners could optimize their routing and track and trace the shipments. Furthermore, the whole supply chain should have been digitally visible which fosters transparency and also could generate meaningful background information for ULaaDS.

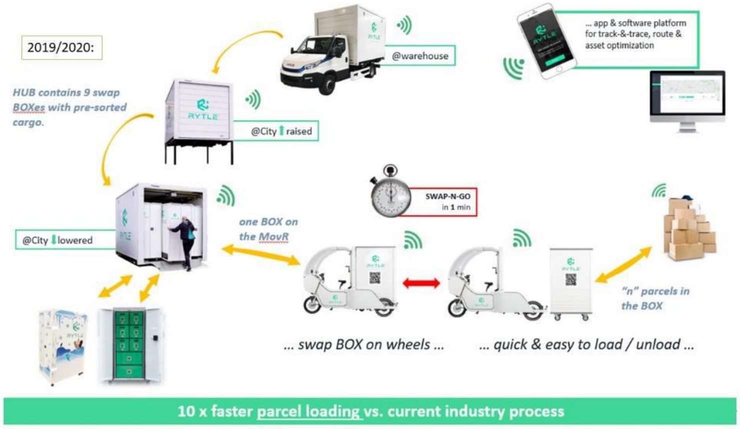


Figure 5: Technical solution promoted by Rytle for the shared public microhubs in Bremen

Effects on System Architecture:

Rytle offers not only cargo bikes, but also pre-sorted swap bodies and an app providing the possibility to collect transport-related data. When talking to the bike couriers involved in the research trial, responsible for the last mile deliveries, it became clear that there was no use of an app and pre-sorted swap bodies. Additionally, other digitized solutions containing for example digital waybills were not implemented. Most of the processes which could have produced digitized data are still done based on manual data.

These are some reasons, why the data basis for evaluation is rather small. Nevertheless, the project partner tbnlr provided the researcher team of ULaaDS with insights regarding monthly shipping volumes as well as background information regarding cost positions and the execution of processes. To this point (06/23), the qualitative feedback was extended by interviews with the bike couriers.

The system architecture helped in this trial to foster the communication transparency between partners and also show up problems which then could be escalated to the project coordinators to keep them informed. Furthermore, deviations were elaborated collaboratively to mitigate the impact of data gaps.

4.1.2 Trial 2 – Private micro-logistics (network of cargo-bike rental-stations)

The second trial focusses on private logistics. Within the ULaaDS project and together with ADFC, Bremen integrated five new cargo bikes in their city-wide sharing fleet. Therefore, this trial is a complementary measure for private micro logistics in the city of Bremen. The use of the cargo bikes should be connected to a little monetary compensation.

An online booking system offers users the possibility to book their preferred slots to rent the cargo bikes, use them and return them to the rental location once done. By this trial, car trips for private logistics should be avoided, thus reducing pollution and congestion.

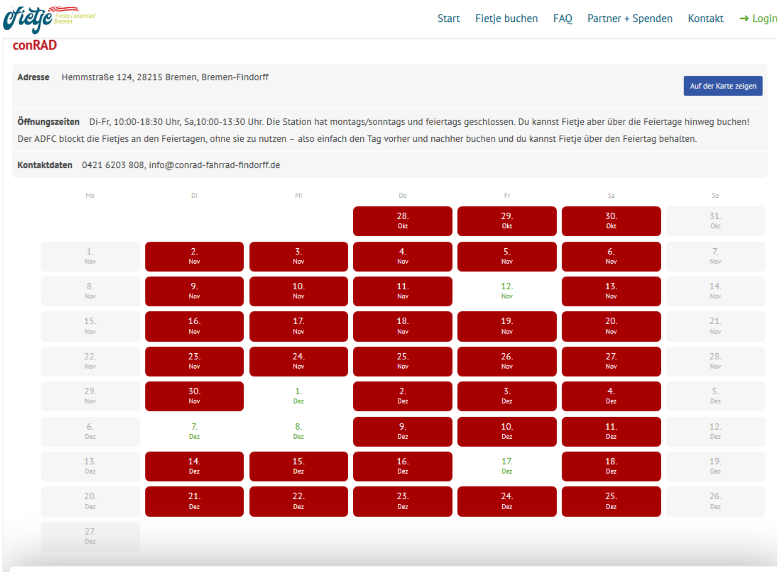


Figure 6: Online cargo bikes booking system for private micro-logistics in Bremen

Effects on System Architecture:

ADFC Bremen used different methods to gain quantitative insights regarding this trial. Especially, surveys conducted to gain information about the users itself (like gender, age) and their use patterns (inter alia reason for usage, estimated kilometers driven, mode of transport substituted) are meaningful data sources within ULaaDS. As these were online surveys, it is also possible to easily carry out tabular evaluations.

With respect to the DMP and using the system architecture, the data could be systematically catalogized and the data flow was communicated transparently between the partners involved.

Nevertheless, some aspects regarding the system architecture and data collection could be improved for future developments in this field. Especially, the use of GPS sensors and a more detailled booking system was asked for by the research team and communicated to the trial leaders. Insights could have been inter alia more detailed information about the (un-)used time, highly frequented routes and thus lead to a better design of the overall cargo bike sharing system.

4.1.3 Trial 3 - Cargo-hitching

For trial 3, Via and Bremen explored a trial for on-demand urban logistics using electric vans to offer on-demand pooling for cargo and passengers. Partners looked at two options: (1) a trial in collaboration with Daimler at their local plant in Bremen, or (2) a virtual trial on different models of combined passenger and parcel transport in a residential area in Bremen.

Although initially assessed that Via and Daimler had experience working together on transport topics, and the location could have been suitable, the virtual trial was preferred. Reasons were inter alia concerns from the Daimler management about the optimisation potential, as well as external factors affecting the operational work of the partners involved (like global supply chain challenges, COVID). Thus, the virtual trial started in the beginning of 2023 by means of simulation based on real-world data.

Effects on System Architecture:

Due to the explorative nature of the trial, there had been no quantitative data exchange between different partners by June 2023. In bilateral meetings, Via explained its simulation approach and the parameters used for calculation to interested parties of the Bremen trial. Also, a report draft was provided. The private actor (Via) and the local municipality agreed on two simulation scenarios in the context of cargo-hitching that are useful for the city of Bremen:

[1] A Residential area that would be a viable for on-demand transport and cargo delivery

[2] The Cargo Distribution Centre, also known as the freight village (in German "Güterverkehrszentrum" (GVZ))

It is therefore foreseen for the upcoming project period to ask for more detailed information regarding quantitative data used for the report and the simulations to foster the exchange of (raw) data between the different stakeholders.

4.2 Groningen (Netherlands)

4.2.1 Trial 1 - Platform for sharing ZE vehicles and collaboration in last-mile deliveries

Trial 1 was aimed at developing, implementing, and promoting a platform for the on-demand supply of shops and delivery to consumers in Groningen. The platform was designed to offer local shopkeepers and entrepreneurs access to ZE vehicles for their inbound and outbound logistics processes, thus increasing the efficiency/use of transport vehicles and reducing overall CO_2 emissions. Different stakeholders were involved in this trial: The Groningen City Club took care of the needs of the vehicle users during the trial and communication procedures. RUG analysed the quantitative data provided by the mobility solutions provider. Furthermore, they conducted two rounds of interviews with the (potential) users of the system. Last, a mobility solutions provider was part of the trial which provided the vehicle and took care of the online portal and mobile app (see Figure 7), through which users could reserve a vehicle.

Figure 7: Screenshot of the mobile app used for sharing ZE vehicles in Groningen

The quantitative data like reservation information of this trial were provided by the mobility service providers applications. Consent about this procedure was given by the shopkeepers involved in the trial and the mobility solutions provider for ULaaDS. This is the reason why the project partner RUG could derive valuable insights for all partners involved in this trial covering aspects like e. g. the average trip duration and mileage, usage rate over the assessment period and therefore justified assumptions about costs for average trips.

Effects on System Architecture:

Due to clear responsibilites in this trial, meaningful insights could be derived by the scientific partner RUG based on the cooperation of the private companies and city of Groningen. Expected outcomes and the need for data-related cooperation was communicated during the implementation and execution period of this trial.

The app as digitized solution offered the possibility to gain information about use patterns while also further analysis where possible, e. g. about distances driven. Qualitative feedback was given by the participants during the local fora as well as during interviews where the scientifc partner RUG could derive insights about lessons learned inter alia about the booking system but also to validate quantitative insights that needed more background information. An example is the booking of shared vehicles overnight which was a convenient way for some users involved in this trial as the return was postponed.

Therefore, the local partners involved where informed about the data processing procedure while also the partners of the ULaaDS consortium were regularly informed, e. g. during project meetings, what outcomes to expect and how data can be shared.

4.2.2 Trial 2 - Mobi/logihubs around the city: smart lockers on park and ride zone

As presented in chapter 3.3.2, the Mobi/logihubs trial in Groningen did not take place in its original form. Due to technical issues related to the connection to the electric grid, it took much longer than anticipated to install the smart lockers at the park and ride zones in Groningen. Nevertheless, the trial leaders changed the trial's scope during the project period which led to a broader examination of the topic of parcel lockers in the city's environment. One of the results of this process and the connected local fora was that when LSPs request the use of public spaces for parcel lockers, there is an opportunity for municipalities to negotiate and set requirements when parcel lockers are to be placed in public spaces.

Effects on System Architecture:

On the one hand, due to the smart locker not yet being operational by June 2023, a data exchange between different partners as initially envisaged never took place and the proposed system architecture was not used. On the other hand, the shift of the scope during the project period offered another point of view regarding parcel lockers and their placement in urban environments. BAX, RUG and the City of Groningen have engaged in thorough information exchange about public datasets, such as the locations of mobility hubs and street networks, in conjunction with proprietary data like existing parcel locker and PUDO systems. These aspects will be used to come up with a policy framework for parcel locker placement in public spaces. Furthermore, this framework will serve as the basis for a public tender for parcel locker services (to be published before the end of 2023).

This deliverable D 3.4 also proposes to foster an exchange of data related to the parcel lockers (e. g. anonymised utilisation data, rate of turnover, frequency of deliveries). This could allow external partners (like the city offering the public space) to evaluate their benefits and trade-offs and derive impact-related insights for the specific urban environment.

4.3 Mechelen (Belgium)

4.3.1 Trial 1 – Logistics ecosystem for parcel delivery in the inner city

As presented in chapter 3.3.2, the first of the two trials in Mechelen did not result in deployment of the solution. VIL, as responsible partner in the pre-trial set-up, concluded that several aspects led to this decision, mainly related to incompatibilities between the participating private companies UPS, Bpost and ECOkoeriers. At this point, reference should be made to the upcoming deliverable D 4.7 which focusses on the summary of the research trials.

Effects on System Architecture:

Due to this fact, a data exchange between different partners never took place and the proposed system architecture was not used.

4.3.2 Trial 2 – The role of autonomous vehicles in parcel deliveries

The aim of this trial was to test the concept of "cargo hitching", the combination of freight and public transport. Furthermore, to increase the level of service, the combination with an autonomous shuttle was trialled. The trial participants have different backgrounds: EasyMile as the provider of the autonomous vehicle, Bpost as LSP taking care of the dynamic parcel locker, VIL responsible for the scientific accompaniment and the city of Mechelen as patron of the whole trial.

The route chosen for this trial was in the industrial area called “Mechelen-Noord” within the city region of Mechelen. The route of the autonomous shuttle is shown in Figure 8. The locations of these stops were chosen to be close to businesses that supported the project and to existing bus stops that the shuttle passed on its route. In contrast, however, the main stop was located in a car park, where an existing Bpost locker was already placed which affected the use of the dynamic parcel locker.

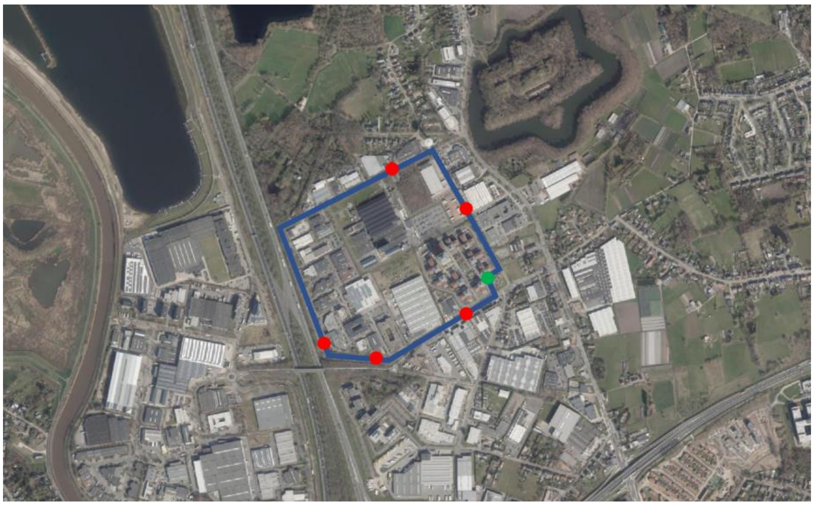


Figure 8: Route of the autonomous shuttle (blue line), stops (red dots) and main stop (green dot) in Mechelen

Effects on System Architecture:

During the trial and the bilateral meetings of the trial leaders and researchers in ULaaDS, it became clear that the scope shifted a little in this trial to the direction of raising user awareness of current technological possibilities and examining the acceptance of an autonomous shuttle. Nevertheless, on the one hand, input from the KPI list defined in D5.1 was used to quantify the land use effects and environmental impact of the autonomous shuttle.

On the other hand, the circumstances of the trial made an evaluation from a logistical point of view difficult. The vehicle provider EasyMile mainly provided data generated by the autonomous vehicle itself which was used for the aforementioned impact assesement. Furthermore, due to a Non-Disclosure Agreement (NDA) these data cannot be made publicly and can only be used and evaluated by the respective partners. The locker was not used that frequent as expected in advance, also due to its competition with the static parcel locker and the lower level of convenience for the users of a dynamic parcel locker.

Due to the NDA by EasyMile, data exchange was reduced to PDF-files containing condensed information about the vehicle operations. The partner VIL described in D4.4 “Mechelen ULaaDS practical research trials” the quantitaive impacts but the main focus of this internal document were qualitative impacts. The main reason for the shift was the rather low technology readiness level (TRL) of this solution. Furthermore, the deployment of the autonomous vehicle was for many stakeholders a first point of contact with this technology. Therefore, the data exchange and the proposed system architecture was not that crucial for executing the processes and for deriviation of meaningful insights.

5. Derivations

As presented in the previous chapter, one of the solutions did not reach the deployment stage, some others underwent different changes in terms of their scopes while yet others got to the point of data exchange. Due to this fact, this chapter focusses on how to overcome the challenges associated with data exchange between different entities. Therefore, several (counter-)measures can be implemented in advance or during the operation of trials. These countermeasures aim to address the specific challenges and ensure smooth, reliable, and secure data exchange.

[1] Expectation Management:

In advance of setting up trials, the respective partners should get together to evaluate possibilities of exchanging data between the involved stakeholders. The scope and aim of the trials as well as the data necessary to derive meaningful insights should be communicated in advance to address all expectations as well as concerns of the participants. Otherwise, there is a certain threat to not meet the initial expectations which can lead to disappointment of one or more involved partners. Furthermore, the full potential of insights is not exploited. This task also covers the implementation of countermeasures in advance to the trials that can help to overcome data gaps (e. g. installation of sensors, communicating of a proposed system architecture).

[2] Trust and Collaboration:

Fostering open communication and collaboration between entities through e.g. regular meetings was crucial for the trials in ULaaDS. Related to this aspect is the establishment of data sharing agreements that clarify expectations, data ownership, and usage rights which was mainly done by using NDAs. The receiving party also has to ensure transparency and clear documentation regarding data handling, security practices and the processing of data. Documents like this deliverable also aim to foster transparency regarding data flows, responsibilities as well as duties.

[3] Data Governance and Compliance:

Additionally and related to “Trust and Collaboration”, it is fundamental to establish data governance frameworks and policies to ensure compliance with relevant regulations. In ULaaDS, deliverables like the DMP act as a guiding document regarding data governance to oversee data exchange initiatives and address concerns related to legislative frameworks like GDPR. Furthermore, it was communicated that no personal information concerning the research trials is shared between partners. If necessary, the data were anonymized or pseudonymized to protect sensitive information. Clear data sharing agreements and consents need to be communicated and maintained in advance, throughout and after a project period. Measure can be regular audits and assessments to ensure adherence to data protection regulations.

[4] Security Issues:

To exchange data between different partners, strong authentication mechanisms such as two-factor authentication or multi-factor authentication should be implemented. In ULaaDS, most of the data is exchanged via cloud storage system of the project partner IML. Access is controlled by e-mail addresses and only authorized entities can access the research trial data. Furthermore, the storage system is regularly updated and patched to address security vulnerabilities as well as equipped with threat detection and prevention mechanisms.

[5] Data Quality and Integrity:

The implementation of iterative data validation checks is proposed to ensure data quality during the exchange process. By establishing data governance practices, it is possible to detect data gaps and to improve data quality across systems. Practices in ULaaDS cover regular check-ups and status updates between respective partners to enable the derivation of meaningful insights for the consortium but also a greater audience after the project period but also to communicate restriction in the analysis of data due to e. g. data gaps.

Not part of ULaaDS but foreseen for other initiatives in this field, is the processing of larger data amounts from several sources. In this case, checksums or digital signatures help to verify data integrity. Also, error detection and correction mechanisms during data transmission should be implemented as manual checks reaches its limits.

[6] Interoperability and Data (In-)Compatibility

By defining and enforcing standardized ways for data exchange procedures in advance, the partners involved foster the interoperability and compatibility of systems across entities during the actual trial execution. This leads to efficiency gains over time. If necessary, interfaces, protocols, and APIs for data exchange can be defined in advance. In ULaaDS this was not necessary as most quantitative data that was transferred were Excel spreadsheet or in CSV-format. The latter makes the processing for third parties easier as its machine readable and can be fed easier into other software environments without additional transformation steps if well formatted.

[7] Dependency on (Manual) Legacy Systems:

Some of the trials in ULaaDS provided data but used (manual) legacy systems. Examples are e. g. the booking system and localisation of the privately used cargo bikes as well as using manual waybills for the micro depots in Bremen. To foster more transparency and gain more insights, middleware or solutions that bridge the gap between legacy systems and modern technologies should be integrated. New sources of data can be relatively cheap. Regarding the privately used cargo bikes, one can use in the future GPS sensors to locate the bikes and track and trace their movements to derive insights of the use patterns. Therefore, it is proposed to gradually migrate or modernize legacy systems to support data exchange requirements.

Implementing these countermeasures requires a combination of technical solutions, organizational processes, and collaborative efforts between entities. By addressing the specific challenges and implementing appropriate measures, entities can overcome the problems associated with data exchange and establish a more efficient and secure data sharing environment.

6. Conclusions

This document provides the proposed modular system architecture for ULaaDS, outlined benefits and challenges of implementing a system architecture in general as well highlighted experiences made from real-life data collection. The architecture was intended to be built in a modular and generalized way. On the one hand, the modular approach in ULaaDS allows for an efficient integration of/adaption to changes regarding data issues, e. g. managing the data repositories, designing the required interfaces among project partners as well as storing, processing, and working with the raw data to derive new insights. On the other hand, the generalized approach was chosen to act as a blueprint for future developments in this field which also include data exchange between partners of private companies, municipalities, and researchers.

It was foreseen that the stakeholders of the different research trials may use different data formats and terms which need to be aligned and translated, e. g. using operational standards. At this point (06/23) the data collection and exchange has reached a lively level. Collaboration was established by technical solutions, organizational processes, and collaborative efforts between the entities. Even though, KPIs were defined at the beginning of the project, not all were addressed. Therefore, this deliverable proposes to bring expectation management and the related processes like data definitions forward in time, preferably during the period of idea generation. The final assessment based on the indicators defined by TOI and provided by the research trial leaders is not finalized yet and is foreseen for the upcoming project period. Also in an upcoming step, the integration into the toolbox of WP 6 is foreseen as its highly dependent on the insights derived from the impact assessment.

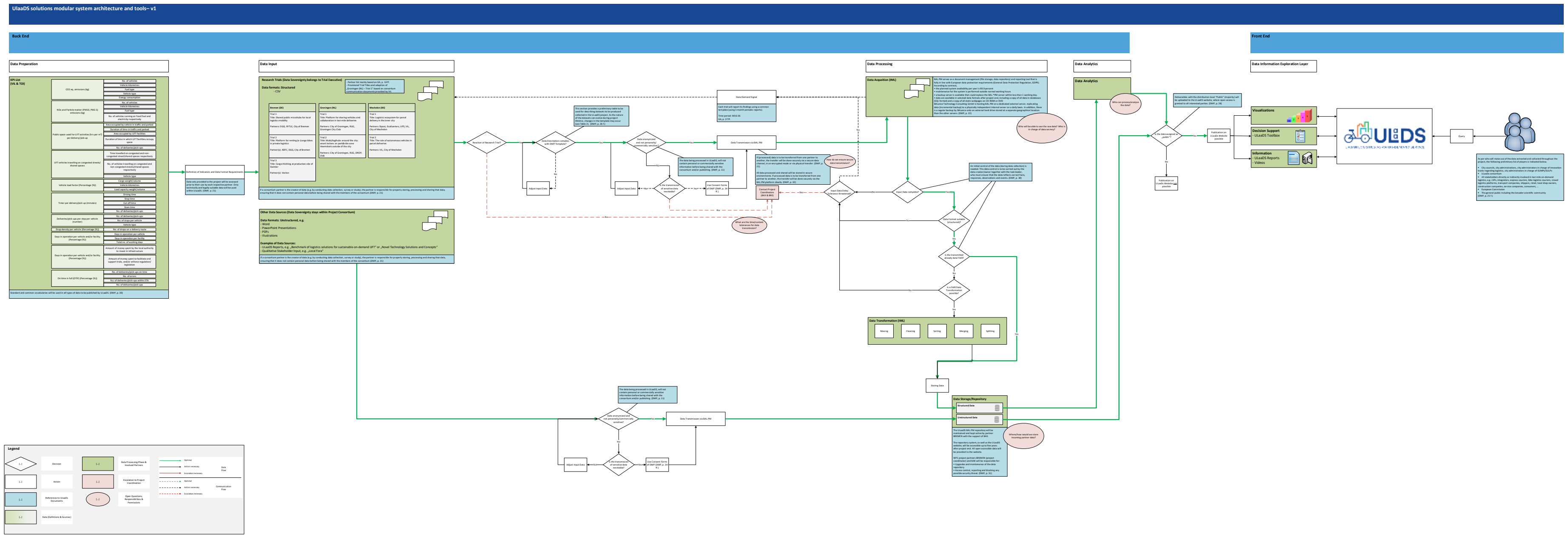
In conclusion, the goal of the system architecture regarding data exchange between different entities was and is to establish an efficient, transparent, and reliable framework for the exchange of information. The system architecture refers to the overall design and structure of a system, including its components, interfaces, and relationships. When it comes to data exchange, the system architecture aims to facilitate the seamless flow of data between various entities. Even though, the specific objectives of the involved stakeholder can vary depending on their context and common goals defined, it was underlined that the cooperation of different stakeholders in the context of (sustainable) urban logistics and the exchange of proprietary data can lead to a better understanding of processes for all partners involved.

Acronyms

Acronym	Meaning
API	Application Programming Interface
D	Deliverable
DMP	Data Management Plan
EDI	Electronic Data Interchange
GDPR	General Data Protection Regulation
GVZ	Güterverkehrszentrum
IML	Fraunhofer Institute for Material Flow and Logistics
KPI	Key Performance Indicator
LSP	Logistics Service Provider
RUG	Rijksuniversiteit Groningen
T	Task
TOI	Transportøkonomisk institutt
TRL	Technology Readiness Level
ULaaDS	Urban Logistics as an on-Demand Service
WP	Work Package
ZE	Zero emission

Appendix

Modular System Architecture



The ULaaDS project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 861833. ULaaDS is a project under the CIVITAS Initiative.