D E L P H I

FeDerated nEtwork of pLatforms for Passenger and freigHt Intermodality

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D3.3: Multimodal, technology-agnostic services, interoperability and legacy systems

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Executive Summary

The following text is a generic guideline for the authors to produce the Executive Summary section. This text marked in purple should be deleted before submitting for internal review.

Please follow these guidelines:

- ***Length:*** *please limit it to one page (2 pages in exceptional cases).*
- ***ALL deliverables*** *must have conclusions.*
- ***Goal:*** *The Executive summary is not an "introduction" to the deliverable. The main goal of this section is to provide readers with a whole picture of the document (i.e., the Abstract section from the papers), so that they can understand the content of the deliverable at once without further reading.*
- ***Self-contained:*** *If there is any input coming from other deliverables, it must be mentioned here.*
- ***Motivation for the reader*** *(Recommended: 1 –10 lines):*
  - *What is the reason for being for this deliverable? Which challenges it addresses?*
  - *What will the reader learn from it?*
- *Main results and findings (Recommended: 5 to 50 lines):*
  - *What are the main results achieved?*
  - *How does it contribute to the DELPHI context?*
- *Short conclusions (Recommended: 1 to 10 lines):*
  - *Key take away messages.*

Add your text here.

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Abbreviations & Acronyms

Abbreviation / acronym	**Description**
EC	European Commission
D1.1	Deliverable number 1 belonging to WP 1
WP	Work Package

1. Introduction

1.1 Purpose of the document

Explain why the document is created, what purpose it serves in the project, who are the "customers" e.g., what WPs or Tasks are going to use the deliverable – what question it answers …

Text

1.2 Intended readership

Explain who is the intended audience for the deliverables, e.g., the clients of this deliverables, if public, who is likely to be interested in the content, research, policy, business …

Text

1.3 Document Structure

Explain the structure of the document, what will be in the next chapters …

Text

2. Legacy Systems Across Use Cases

2.1 Overview of Identified Systems

Text

2.2 Cluj-Napoca UC (Romania)

The Cluj-Napoca Use Case focuses on integrating multiple multimodal mobility and environmental data sources from the Cluj-Napoca Municipality and its metropolitan area, aiming to enable real-time data interoperability and analytics-driven optimisation of urban mobility. The objective is to unify fragmented legacy systems — covering public transport, bike-sharing, parking, and traffic monitoring — into a harmonised data-sharing architecture aligned with DELPHI's interoperability framework.

The systems identified as relevant legacy sources are summarised below, including their roles, exchanged datasets, interdependencies and known limitations.

2.2.1 Public Transportation System – Compania de Transport Public (CTP)

The Public Transportation System operated by CTP constitutes the central mobility infrastructure for Cluj-Napoca and its metropolitan area. It manages 49 urban bus lines, 11 trolleybus lines, and 4 tram lines, in addition to suburban routes extending to six neighbouring communes. The system provides both real-time telemetry and historical datasets, including GTFS schedules and routes, AVL (Automatic Vehicle Location) data, ticket validations (excluding SMS payments), and passenger counts from onboard sensors.

Data are accessible through the Tranzy.ai platform Figure 1, which offers APIs in GTFS and JSON formats. Real-time vehicle positions and arrival predictions are refreshed at short intervals, while historical route and schedule data support performance analytics and optimisation.

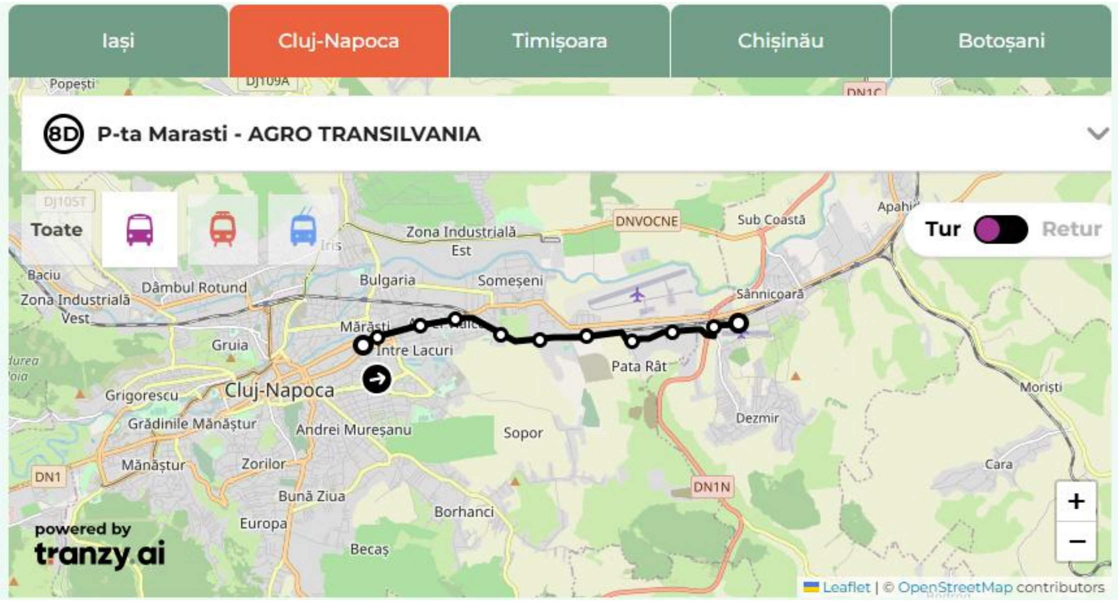


Figure 1. Tranzy.AI Public Transportation Data

Dependencies: CTP data serve as the main source for monitoring public transport operations, calculating travel times, and supporting multimodal route planning when integrated with bike-sharing and parking data.

Known limitations: Certain endpoints enforce rate limits, and not all data (e.g., ticket validations or crowd counts) are openly available through APIs. Some feeds may experience temporary latency or limited update frequency during maintenance operations.

2.2.2 Bike-Sharing System – Cluj Bike

The Cluj Bike system, managed by the Municipality of Cluj-Napoca, provides automated bicycle rental services through 50 stations (Figure 2) distributed across the city and metropolitan area. The system exposes real-time data on bike and dock availability, as well as historical usage logs covering pick-up and drop-off events.

Figure 2. Cluj Bike Station

Data are provided via REST APIs in JSON format, supporting integration into multimodal trip planning services and mobility dashboards.

Dependencies: Bike-sharing data are crucial for last-mile analysis and the development of intermodal routing scenarios combining public transport, biking, and walking.

Known limitations: Rate limits and non-uniform update intervals may affect the timeliness of data. Detailed trip-level information remains stored in internal databases and is not publicly accessible via API.

2.2.3 Public Closed Parking System – MCN

The Public Closed Parking System operated by the Municipality (MCN) provides structured, barrier-controlled parking facilities strategically placed across the city Figure 3. Each parking area is equipped with sensors that record space availability, entry and exit counts, and usage statistics over time.

Figure 3. Cluj-Napoca Parking

These datasets are exposed through a non-standard JSON API, delivering near-real-time information on capacity, occupancy, and short-term usage trends (5-, 10-, and 15-minute intervals).

Dependencies: Parking availability data are used to enhance multimodal journey planning, enabling car users to transition to public transport or bike-sharing options efficiently.

Known limitations: API documentation is limited, and endpoints may impose rate limits or provide inconsistent historical data. Additionally, older applications such as Cluj Parking have been deprecated and are incompatible with current Android versions.

2.2.4 Air Quality Monitoring System

The Air Quality Sensors operated by the uRADMonitor collect environmental data across Cluj-Napoca, measuring particulate matter (PM2.5, PM10), nitrogen dioxide (NO_2), and other key pollutants. The data are published via JSON-based APIs and updated at regular intervals to support environmental analytics and urban mobility correlation studies.

Dependencies: Environmental data enable the assessment of mobility impact on air quality and can be integrated with traffic and transport datasets for predictive modelling.

Known limitations: Some sensors provide delayed updates, and the API may enforce access restrictions or low refresh rates due to bandwidth and privacy considerations.

2.2.5 Public Information Displays – Bus & City Stations

The Information Display System consists of digital panels installed at bus stops and key public locations. These displays provide real-time bus arrival times, schedule deviations, and alerts, sourced directly from the CTP and Tranzy.ai feeds.

Data are available via municipal APIs in JSON format for authorised integrators, offering synchronised public transport status updates.

Dependencies: The system complements the public transport data feeds by offering a visual, user-facing layer that can be leveraged for validation and monitoring of real-time information accuracy.

Known limitations: Data access is restricted to internal municipal systems and selected partners; frequent updates may be subject to rate limitations.

2.2.6 Traffic Data – Waze Partner Hub

Through the Waze Partner Hub, the Municipality collaborates with Waze Mobile Ltd. to access real-time and historical traffic incident data for the city and its metropolitan area (Figure 4). The managed polygon area covers the full urban region of Cluj-Napoca.

Data include incident alerts, congestion levels, and abnormal traffic patterns, updated every two minutes. Integration is achieved via the Waze Partner API, which supports JSON and XML formats and can be connected to Google's BigQuery and Looker Studio for advanced analytics.

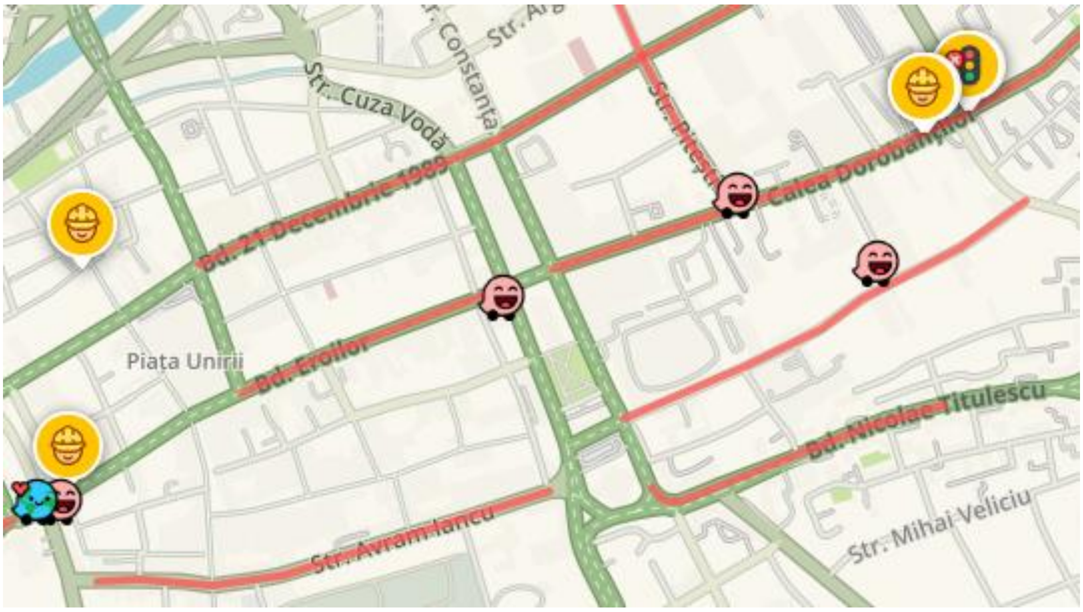


Figure 4. WAZE Data Sample

Dependencies: Waze data provide contextual insight into traffic dynamics and can support predictive models for congestion management and adaptive multimodal routing.

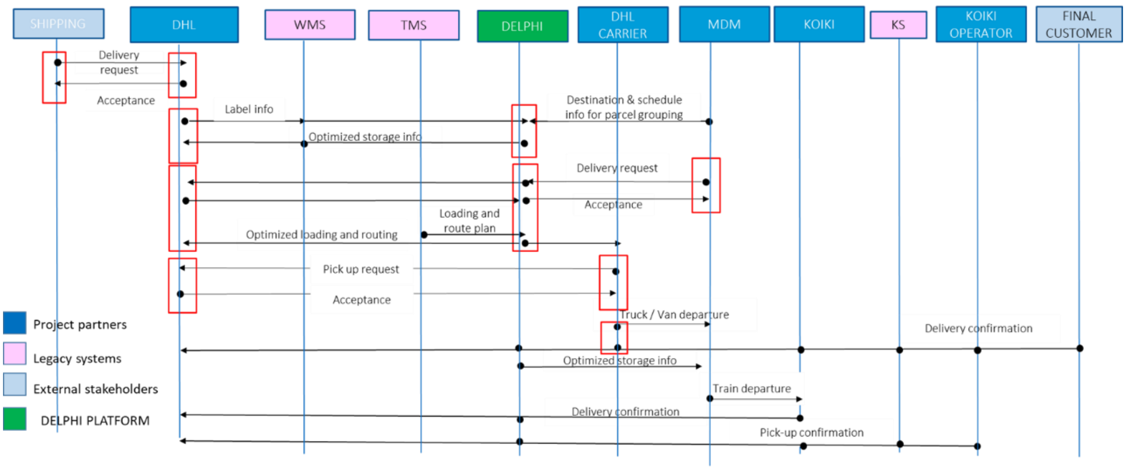
Known limitations: Access to data is regulated by Waze's partnership terms. Rate limits and format restrictions apply, and data may experience brief latency during high-traffic periods or platform maintenance.

2.2.7 Summary and Outlook

The Cluj-Napoca Use Case integrates a diverse ecosystem of municipal and third-party legacy systems, each providing essential data streams for urban mobility optimisation. Despite the heterogeneity of data formats and limited interoperability, these systems collectively form the foundation for the DELPHI Task 3.3 objective: to establish a unified, interoperable, and technology-agnostic data orchestration layer capable of harmonising public transport, parking, bike-sharing, and environmental data into a single mobility intelligence framework.

2.3 Madrid UC (Spain)

Madrid Use Case focuses on the integration of multimodal transport data sources, some of which are not existing at the moment (Metro de Madrid as urban transport mode). Legacy systems form DHL and KOIKI will have to communicate to allow efficient and seamless parcel transportation from the warehouse to the final door destination. Metro will act as a transport node in this chain, and all most data will be invisible for them, except for the number of parcels, Depot, Line and station destination everyday. Metro will not have access to any personal data regarding the final customer nor the content of the parcels. DHL is the legal responsible of preparing the orders and accompanying them in the Metro while KOIKI is the legal responsible of delivering them to their final customer. In all cases, systems will not be directly connected, but anonymised data from them will be used. In the following graph a summary of the information flow and the systems interactions is shown.



2.3.1 Warehouse Management System data (DHL)

The WMS provides data on the warehouse management directly connected with order preparation: label info (metro Depot, station and final customer delivery adress) and storage info. This data is shared in XML format.

Dependencies: this data comes from DHL and its customers (e-commerce trader for which the warehoused is managed). this data is not dependent on any other data within DELPHI project. Part of it will be exchanged with KOIKI (volume, number of parcels, date, station, final delivery address) and Metro (volume, number of parcels, date, Depot, station). The rest of the data is internally managed by DHL to ensure the most efficient warehouse operation and order preparation.

Known limitations: this data will be anonymised, and access will not be open to anyone accessing the DELPHI platform, but only the critical stakeholders for Madrid Use Case.

2.3.2. Transport Management System data (DHL)

Historical anonymised data related to terrestrial shipments from DHL warehouse to specific areas in Madrid city Centre. The information managed will be: shipment requests, transport routes and schedules, shipment status. The actors involved

Dependencies: the actors involved in this data sharing are: transport agents (e.g. Metro, KOIKI), customers and DHL internal personnel. As the WMS, it will anonymised for this reason. It will be shared in XML format and access granted only with specific request for specific stakeholders.

Known limitations: As the WMS, TMS data used will be anonymised and historical . It will be shared in XML format and access granted only with specific request for specific stakeholders.

2.3.3 KOIKI system data

KOIKI legacy system manages the parcels, dates and routes followed by their personnel within the microhubs and on the final delivery route. A proprietary app is used to track parcels delivery.

Dependencies: it is dependant with the data sets from WMS and TMS from DHL.

Known limitations: the data contains personal details on the final customers recieving the parcels so it will has to be anonymised.

2.3.4 Metro schedule data

Metro has a strict and set schedule for the circulation of the trains from each of their depots and arriving at each of the stations. This is fixed unless a unplanned issue arises. Data is public.

2.3.5 Historical data on specific areas delivery (DHL and KOIKI)

Areas chosen for Madrid Use Case are already served by both KOIKI and DHL independently as well as in conjunction. Historical data from all these possibilities is used to calculate the realistic volume of parcels that KOIKI may be able to handle within the area connected with the microhubs selected and the feasible business volume absorption.

Known limitations: this data is historical and will be anonymised. No personnal data will be provided, just the volumes of parcels and areas served.

2.4 Athens UC (Greece)

The Athens Use Case focuses on the integration of multimodal transport data sources across Attiki Odos (AO) and STASY (Urban Rail Transport S.A.), aiming to support dynamic congestion management and intermodal passenger diversion strategies between road and metro. The overall objective is to enable real-time data fusion and interoperability between motorway traffic information systems and urban rail operation systems, thereby improving travel time reliability and environmental efficiency.

The systems identified as relevant legacy sources are summarized below, including their roles, exchanged datasets, interdependencies, and known limitations.

2.4.1 Traffic Information System – Attiki Odos

The Attiki Odos Traffic Management System constitutes the central infrastructure for monitoring and controlling the flow of vehicles along the A6 corridor and Ymittos Ring. It provides both real-time telemetry (loop detector speeds, occupancy, flow) and historical datasets for model calibration and congestion pattern analysis.

The system supports file-based exports and API endpoints for real-time integration, while event and speed data are exposed in CSV and JSON formats. The system is operated by Attiki Odos S.A. under strict access controls, with latency constraints during maintenance or incident logging operations.

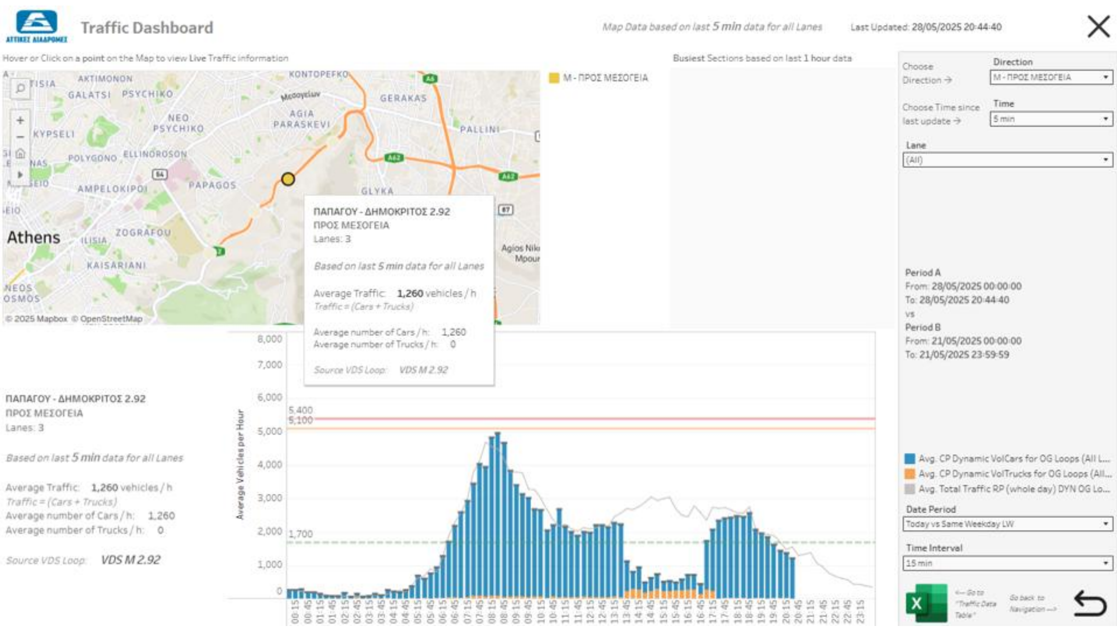


Figure X Attiki Odos Traffic Management System dashboard

Dependencies: The system's data act as the primary input for congestion detection algorithms, EWMA smoothing, and advisory generation. It directly interfaces with the incident management subsystem and indirectly correlates with STASY timetable data for synchronization of diversion triggers.

Known limitations: The data feed is constrained by sampling frequency and occasional latency during system maintenance. Real-time interfaces may impose rate limits, and the lack of multimodal identifiers means that direct correlation with public transport systems requires external alignment. Historical exports are available only on request and may involve approval delays, limiting near-real-time experimentation during pilot runs.

2.4.2 Incident Management System – Attiki Odos

The Incident Management System within AO records traffic incidents, accidents, obstructions, and planned works along the corridor. This data source is essential for shockwave propagation modeling and diversion activation. Event-based logs are available via CSV extracts and secured APIs, typically containing fields such as timestamp, location, severity, and status. Data are continuously updated, though post-validation may introduce minor time lag.

Dependencies: Incident data feed into the advisory engine that determines when and where intermodal diversions are triggered. Correlation with traffic flow data and STASY headways is required to ensure advisories remain feasible within metro capacity constraints.

Known limitations: Since incident registration often involves manual operator input, short reporting delays can occur between event detection and confirmation. Geolocation accuracy may vary across segments due to chainage mapping, and the classification of incidents occasionally requires human validation, introducing minor temporal inconsistencies. Despite these constraints, data quality is sufficient for the validation and testing of advisory algorithms within the Athens UC.

2.4.3 Metro Operations and Scheduling System – STASY

The STASY Metro Operations System manages the scheduling, dispatching, and monitoring of trains, particularly the Airport branch, which runs parallel to Attiki Odos. This system provides timetables, real-time headway deviations, train position updates, and station-level operational status. Data are typically available in CSV or JSON format through secured channels or controlled batch exports. Access is restricted to non-personal, aggregated data, with the possibility of near-real-time updates for pilot validation.

Dependencies: STASY data are essential for computing intermodal ETA, ensuring alignment between road exits and metro departures, and verifying capacity availability during potential diversion events. The system complements AO data by offering the public transport counterpart in the intermodal chain.

Known limitations: Access to real-time operational data is restricted due to internal security and reliability policies. Furthermore, real-time synchronization can be affected by the specified update interval of certain STASY data feeds.

2.4.4 Passenger Information and Ridership Data – STASY

The Passenger Information System aggregates ridership statistics and station throughput for key metro stations relevant to the UC. Data include boarding and alighting counts, aggregated by time window. These datasets are extracted periodically from STASY's internal analytics platform and provided in CSV format. They are anonymized and aggregated to ensure compliance with GDPR and internal data protection policies.

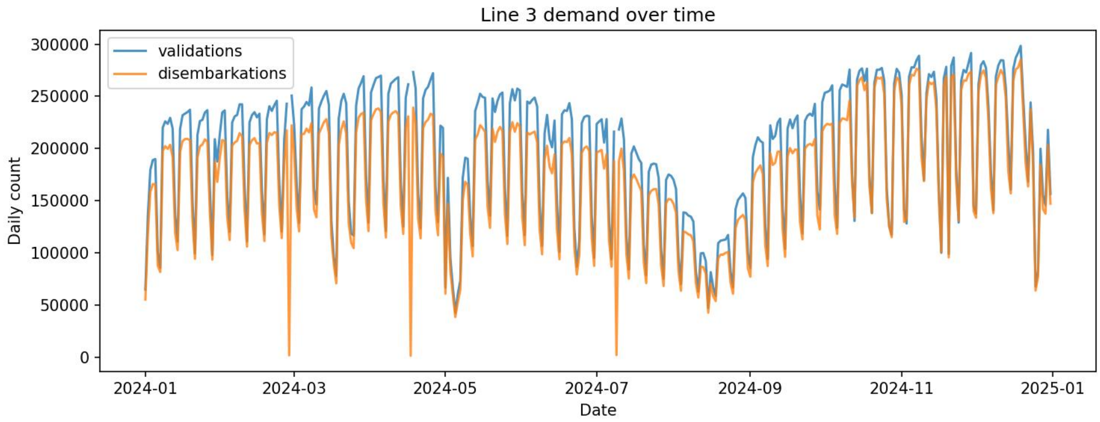


Figure X STASY metro line 3 daily demand for the period 01/01/2024 - 31/12/2024

Dependencies:
Used to assess station load levels and intermodal feasibility under different congestion scenarios. It helps validate whether suggested diversions are operationally viable in real-time or require time-window adjustments.

Known limitations: Ridership data are available at an aggregated temporal level, typically on daily basis, limiting the granularity of intermodal coordination. The frequency of data extraction depends on internal reporting cycles and may not always align with real-time motorway updates. Because of privacy and regulatory compliance, the data are depersonalized and aggregated, preventing detailed behavioral analysis but still adequate for demand estimation and validation of the diversion concept.

2.5 Mykonos UC (Greece)

Brief description of the Systems, Purpose, Datasets, Dependencies, Limitations

3. Interoperability & Connectivity (Reference Model)

In this section we classify the legacy systems described above per system type

3.1 System Type 1

Text

3.2 System Type 2

Text

3.3 System Type 3

Text

3.4 Lessons Learned for Federation

Text

4. Potential Integration into the Dataspace (DELPHI Town Concept)

Text

4.1 Development of Connectors for Data Exchange

4.2 Common Patterns and Interoperability Opportunities

5. Conclusions

References

[1] Papadopoulos, M. (2022). *FeDerated nEtwork of pLatforms for Passenger and freigHt Intermodality* [online] NewYorkNews. Available at: https://www.vehicle.com [Accessed 05 September 2022].

[2] Papadopoulos, S., Li, R., Crome, B. and Graham, J. (2022). *FeDerated nEtwork of pLatforms for Passenger and freigHt Intermodality*, 15, pp.362-369.

Annex 1: Detailed Tables of Legacy Systems

Use Case Name	System Name	Responsible Partner/Owner	System Role/Purpose	Datasets to be exchanged	Data exchange abilities	Data formats	Known Constraints/Limitations
Cluj-Napoca UC (Romania)	Public Transportation System - Compania de Transport Public (CTP)	Cluj-Napoca Municipality	Manages and operates the city and metropolitan area's public transit network	GTFS schedules and routes, real-time AVL (vehicle location), ticket validation (non-SMS), passenger count	Real-time data feed via Tranzy.ai platform, onboard sensors - API	GTFS, JSON	Rate limits may apply; some endpoints may not support high-frequency queries
Cluj-Napoca UC (Romania)	Bike Sharing System - Cluj Bike	Cluj-Napoca Municipality	Provides public access to bicycles via automated stations	Real-time station and bike availability, historical usage data (pick-up/drop-off)	API	JSON	Rate limits may apply; some endpoints may not support high-frequency queries
Cluj-Napoca UC (Romania)	Public Closed Parking System	Cluj-Napoca Municipality	Offers enclosed parking for private vehicles, supporting multimodal transport	Real-time availability and usage statistics	API	JSON	Rate limits may apply; some endpoints may not support high-frequency queries
Cluj-Napoca UC (Romania)	Air Quality Sensors	Cluj-Napoca Municipality	Monitors air quality across the urban environment	PM2.5, PM10, NO2 levels and other metrics	API	JSON	Rate limits may apply; some endpoints may not support high-frequency queries
Cluj-Napoca UC (Romania)	Information Displays (Bus & City Stations)	Cluj-Napoca Municipality	Provides real-time transit updates and schedules in public spaces	Official schedules and real-time data feeds	API	JSON	Rate limits may apply; some endpoints may not support high-frequency queries
Cluj-Napoca UC (Romania)	Waze Partner Hub	Cluj-Napoca Municipality - Waze Mobile Ltd collaboration	Provides traffic insights, incidents, and congestion data	Real-time and historical traffic incidents, alerts, congestion metrics	Real-time data feed via WAZE platform - API	JSON	Access subject to Waze terms;Rate limits may apply; some endpoints may not support high-frequency queries
Mykonos UC (Greece)	e-Ticketing Mykonos Public Transport (KTEL)	KTELM	Provision of number of passengers/luggages per trip	Historical data of passenger number, batch mode daily data extraction	Database view	Delimited	Closed legacy system, periodical data extraction is possible
Mykonos UC (Greece)	Fleet Management System Mykonos Public Transport	KTELM	Bus and van schedules, traffic management data	Historical data of trips and traffic management data, batch mode daily data extraction	File extraction	Delimited	Closed legacy system, periodical data extraction is possible
Mykonos UC (Greece)	Flight Schedules	Fraport	Flight schedules	Historical data of flight schedules	Web site data extraction	Delimited	Online data access
Mykonos UC (Greece)	Vessel schedules	Limeniko Tameio Mykonos (Mykonos Port)	Vessel schedules	Historical data of vessel schedules	Web site data extraction	Delimited	Online data access
Athens UC (GREECE)	Traffic information in Attiki Odos	Attiki Odos	Traffic insights overniew	Real time and historical congestion metrics	File extraxtion	csv	Online data access
Athens UC (GREECE)	Traffic incidents in Attiki Odos	Attiki Odos	Traffic incidents in Attiki Odos	Real time and historical traffic incidents	File extraxtion	csv	Online data access
Madrid UC (Spain)	Warehouse Management Sysrtem	DHL	Manages internal warehouse operation, recieving freight, and order preparation to be sent	Historical data on e-commerce order preparation for a full year	File extraction	xls	Anonimysed data
Madrid UC (Spain)	Transport Management System	DHL	Manages transport routes for delivery of e-commerce orders	Historical data on e-commerce order deliveries for certain postal codes in Madrid	File extraction	xls	Anonimysed data
Madrid UC (Spain)	KOIKI internal management system	KOIKI	Manages the last-mile delivery performed by KOIKI (e.g. client, route, number of parcerls, etc.)	Historical data on deliveries carried out by KOIKI in a certain postal code	File extraction	xls	Anonimysed data
Madrid UC (Spain)	Madrid UC (Spain)	MDM	Manages and operates the metro network in madrid. Provides trains and infraestructure for e-commerce delivery from the outskirts of the city to the city center.	Historical data of Metro trains scheudles	File extraction	xls	Online data access

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