Acumen

D6.3 Pilot reports and synthesis

November 29, 2024

Lead Beneficiary: UniLu

Funded by the European Union

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General Information	
Grant Agreement Nr	101103808
Action Acronym	ACUMEN
Action Title	Ai-aided deCision tool for seamless mUltiModal nEtwork and traffic manageмeNt
Type of Action	HORIZON - RIA
Call	HORIZON-CL5-2022-D6-02
Start Date and Duration	1st June 2023 – 31st May 2026
Due Date of the Deliverable	M18
Submission Date	November 29th, 2024
Lead Beneficiary	UniLU
Deliverable Dissemination Level	Public

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Revision History		
Version	**Date**	**Comments**
0.9	15/11/2024	First draft for review
0.95	20/11/2024	Reviews by LIST
1.0	30/11/2024	Final version
1.1	07/07/2025	Emblem and disclaimer updated

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Executive Summary

This deliverable provides the general overview and synthesis of pilot results from Tasks 6.2-6.5 up to the time of the submission. The scope of this document is to report the set up and the work in progress of the four pilots, and to monitor the quality and timely progress of all activities planned up to this reporting deadline.

Following a similar structure and template used for Deliverable 6.1, each section dedicated to a specific pilot has been subdivided into subsections each focusing on the data collection and analysis progress, the model developments and the eventual other related preparatory or demonstrating activities (e.g. ex-ante surveys). Additionally, any deviation observed or planned to the original plan has been included and justified.

All four pilots are progressing smoothly following the timelines specified in Deliverable 6.1. More specifically, the Athens pilot has progressed in collecting on-field data of vehicle trajectories, and further discussions on the Athens Digital Twin developments have been ongoing. Role and performed tasks and activities by partner have also been described. Concerning Helsinki, some modification of the timeline has been reported, e.g. to accommodate the rescheduling of the drone data collections. Preliminary results of the collected trajectories have been shown, together with the progress in terms of model developments and Digital Twin integration. The simulation platform for the Amsterdam pilot is advancing and scenarios involving specific network disruptions are being developed. Finally, the preparation of the on-demand service, the progress on the simulations and discussions on the modifications of the Luxembourg pilot in response of the changes in the consortium and reallocation of resources is presented.

Success and steps for further improvements are finally summarized in the conclusions and will be incorporated in the next version of this document, due at the end of the project.

Lessons learnt will feed into WP7.

1. Pilots Summary

1.1. Overview of 4 pilots

In this project, we are conducting 4 pilots in Athens, Amsterdam, Helsinki, and Luxembourg, to demonstrate the effectiveness of the innovative methods and tools developed in this project. Those four pilots were carefully chosen at the proposal writing stage to range across different operating contexts and scales, mobility needs and patterns, modes and services, data availability, and tested monitoring and management solutions, and in four different EU countries. The ACUMEN DT platform and the models and AI-aided data-driven tools developed in the project will be evaluated in different use cases encompassing communication and consensus across stakeholders (Athens Pilot), cooperation across different modes (Helsinki Pilot), resilience in response to disruptions (Amsterdam Pilot), and seamless and integrated on-demand mobility within a multimodal door-to-door service (Luxembourg pilot). The table below summarises the expected results from each pilot.

The summary of each pilot is described in the section below.

Table 1-1 The summary of expected results from each pilot

Pilots	Expected Results
Athens	Innovative holistic mobility platform implementation
Helsinki	Multimodal soft (nudges and incentives) traffic management measures
Amsterdam	Coordinated multimodal management for network disruptions
Luxembourg	Multimodal mobility optimisation at the service level

1.1.1. Athens

Pilot overview

The main objective of this pilot is to design, implement, and test an innovative holistic mobility platform for decision-making in the Athens Metropolitan area considering private cars, trucks/last-mile delivery, and public transport. The pilot focuses on designing an innovative holistic mobility platform with the capability to accept multimodal input from all kinds of data sources (terrestrial and aerial), provide transport/traffic analytics, make multimodal short-term traffic predictions (private car and public transport), and provide a simulation/decision making tool for the transport and city authorities. This will be integrated into a Digital Twin (indicatively based on the DT approach developed in the framework of the DUET - H2020) and is expected to provide a powerful tool for traffic analysis and prediction for the Traffic Management Centre of the Attica Region. The platform will be calibrated with real-life data: HERE will provide traffic data and technical support for integration of the data into the simulation model, while MOBL will provide detailed trajectories for all vehicle types and data on freight and last mile delivery for the city centre using drones. It will also contribute to monitor and anonymously identify on-street illegal parking. Other traffic data will be gathered from loop detector sensors and cameras, transit ticket data, transit occupancy data, bus fleet location data, signal plans, weather data, emissions and noise data, trajectory data from open sources, and openly available data from region authorities and governmental sources. In addition to the above mentioned, a visualisation tool and Decision Support System (DSS) will be integrated in the ACUMEN seamless and integrated traffic management framework.

All the above are to lead in the formation of the ACUMEN platform. In said platform, the Athens Digital Twin will be integrated as an added value-tool for complete traffic management and forecasting. The scenarios are envisioned to include end-users from all critical stakeholders in the Athens traffic ecosystem such as the Ministry of Transport, public transport companies, city officials, etc. The inclusion of such stakeholders in this process is expected to provide valuable feedback and ensure the applicability and acceptance of ACUMEN solutions. The ACUMEN framework will be tested in forecasting, simulations and traffic management solutions in Athens. The pilot will make use of benchmarking techniques to guarantee the transferability of the solution implemented and tested in the Athens Pilot to other sites.

Changes made from the proposal.

No significant changes were to be reported from the proposal at the time of writing this report.

1.1.2. Helsinki

The pilot project in Helsinki aims to dynamically influence travellers' mode choices in terms of sustainability and citizens' well-being by investigating dynamic traffic in the Helsinki West Harbour area, which is congested various times during a day, including the morning/evening peak, due to arrival /departure of ferries commuting between Helsinki, Finland and Tallinn, Estonia.

The City of Helsinki's innovation company, Forum Virium Helsinki (FVH), in cooperation with the project consortium and involving various stakeholders, is leading and supporting the Helsinki pilot project in developing the concept. Building on the Code the Streets project, the pilot will identify the requirements and interfaces to link the ACUMEN DT architecture, allowing for seamless integration with analytics and AI-powered seamless integrated multimodal traffic management tools. In addition, it will use traffic simulation, as well as drone-collected data. This data will be used for mobility analyses during different stages of the intervention and for calibrating the simulation.

Test users will be offered alternative modes via a traffic-related app. The pilot project will focus on testing the impact of soft measures, such as nudges and incentives, on network-level traffic flows in different intervention phases, taking into account input from end-users, citizens and mobility-related societal considerations, with a focus on climate neutrality.

The Helsinki pilot project expects that the implementation of the ACUMEN project will lead to positive changes in travel behaviour, transport patterns and environmental impacts, contributing to a more sustainable and efficient urban mobility landscape.

Table 1-2 Changes made from the proposal in Helsinki pilot.

Changes	Reasons	Mitigation
The TrafficSense app, originally considered for contacting test users during the second phase of the pilot, is no longer being used due to its outdated source code and incompatibility with the current Android version, as well as its unavailability on iOS systems. Instead, the PayiQ Ticket app has been adopted as the alternative solution for this purpose in Activity No. 7.1	Due to the initial test, it was observed that the TrafficSense app supports older versions of Android. Both the TrafficSense and TravelSense apps were found to be unsuitable for the ACUMEN scenario, primarily because they could not provide the necessary features, such as the ability to incentivize travelers effectively	We will allocate additional time to conduct a thorough feasibility study and confirm the availability of the Traveler App options on both Android and possible iOS systems as well. The features that are not available in the real-world scenario will be deployed into simulated environment and DT.

Route choice is not the focus of the pilot anymore.	Considering route choice puts emphasis on the car trips, while we aim at seamless multimodal transportation network. Thus, the pilot explores the impact of intervention strategies, e.g., nudging and incentivizing, to encourage active and more sustainable modes.	When passengers get off a ferry, they can take a car or tram to get to their final destinations, but we encourage them to replace their current modes with bikes or scooters
The first phase (Phase 1), involving real-life activities in drone data collection, started in September 2023 instead of the originally planned November-December 2023.	The first drone data collection has been conducted in September 2023 (M4) to have favourable weather and lighting weather conditions to capture the actual traffic patterns.	The second phase, Phase 2, will execute real-life activities accordingly in September 2024
Restriction Zones (RZ) is not applicable in the pilot area.	An RZ is typically defined as a specific area where mandatory policies, such as congestion pricing, are enforced for all travelers. However, when using incentives, participation is voluntary and cannot be imposed on travelers. As a result, the concept of a clearly defined RZ does not apply in this context..	Changes in the incentive scheme
Last-mile logistics was removed from the Helsinki pilot	Last-mile logistics was removed from the Helsinki pilot because it was not feasible to implement within the scope of the project. The focus of the pilot is on encouraging travellers to adopt more sustainable modes of transport and on enhancing public transport experiences. Last-mile logistics is a complex issue that requires a separate study and additional resources, particularly for managing sensitive GDPR-compliant door-to-door logistics information.	Changes in the focus scheme
Calibration component T3.3	Not included in the Helsinki pilot	The component T3.3 validation not anymore in the Helsinki pilot

1.1.3. Amsterdam

Pilot overview

The main objective of this pilot is demonstrating how joint multimodal management can enable improved flexibility and resilience when facing network disruptions. The pilot will be implemented in a digital replica of the northern metropolitan area of the city of Amsterdam (NL).

A key corridor connecting the northern part of the metropolitan region to the city centre (road s116) crosses the IJ river through an underwater tunnel (IJ-tunnel). In disruption conditions, the tunnel may be partly (i.e., single direction traffic) or wholly closed. Such closures might be planned (e.g., during maintenance) or unscheduled (e.g., due to incidents, vehicle breakdowns, …). In case of disruption, the traffic control centre of the City of Amsterdam activates a network management scenario, which comprises of physical barriers closing access to the tunnel, a set of variable message panels informing vehicles about the closure and indicating predetermined route alternatives to the city centre, and ad-hoc tuning of specific Traffic Lights along said alternatives.

This pilot will focus on determining under which conditions and assumptions a multi-modal management approach, involving multiple stakeholders (e.g. involving Park-and-Ride (P&R) operators, viable alternative transit connections, car-pooling services) can lead to improved resilience to such disruptions.

Changes made from the proposal.

None at the time of writing.

1.1.4. Luxembourg

Pilot overview

The main objective of this pilot is to demonstrate to what extent seamless and integrated mobility can improve mass transit users' experience. This pilot will be implemented in two sites: (i) Contern, an industrial area where an existing last-mile service connects employers with the nearby train station. (ii) Esch-sur-Alzette, a peri-urban commune south of Luxembourg City that is home to both residential and commercial zones with a mix of employers, services, and activity locations (restaurants, shops). In this pilot, SLA will deploy two types of shuttles.

In Contern, a conventional fixed route and fixed schedule service will be replaced by an optimised on-demand service. This will allow increased responsiveness and flexibility, and seamless integration with mass transit. In Esch-sur-Alzette an autonomous shuttle runs on an 800m route along pedestrian streets with cross traffic. The shuttle currently operates from 11 am to 6 pm with fixed stops and frequency. Companies, users and inhabitants in the area are interested in a more flexible service that will require additional stops or stop skipping. In Esch-sur-Alzette, the pilot will demonstrate the technical feasibility of adding or skipping stops based on actual requests using the autonomous shuttle.[1]

Table 1-3 Changes made from the proposal in Luxembourg pilot.

Changes	Reasons	Mitigation
Autonomous shuttle tasks have been relocated to Esch.	Due to the changes in CEO and market and commercial priorities, SLA decided not to introduce a new autonomous shuttle in Contern. However, SLA has an autonomous shuttle running in Esch and we have therefore moved the autonomous shuttle related tasks to Esch.	Nothing further needed in terms of mitigation. The change of location does not cause any deviation from the objectives for this part of the pilot as the experiment will be conducted in the same way as it was planned for the original location in Contern.

[1] The changes involving the experiment in Esch-sur-Alzette are currently being proposed to the European Commission within an amendment and are therefore subject to approval.

1.2. Pilots' dependency to other WPs

Table 1-5 Table 4-1shows the summary of which tasks each pilot will prove input or validation to. Please refer to Table 1-4 for the name of each WP and tasks. A pilot providing input indicates that data owned by partners involved in a pilot or data to be collected during the pilot will be used for the activities done in a task. A pilot providing validation implies that models and methods developed in each task will be applied and their effectiveness and added value verified in the context of each pilot. The detailed description of how each pilot provide the input or validation will be found in the description of each pilot under the role of Digital Twin section.

Table 1-4 The name of each WP and tasks

WP	Name	Task	Name
2	Decentralised data framework and data-driven descriptive mobility analytics	2.1	Secure- and privacy-preserving data and learning framework
		2.2	Multisource data fusion (analytics)
		2.3	Unexpected mobility patterns identifier
3	Hybrid Intelligence forecasting and simulation framework	3.1	Develop explainable, fair, trustful and resilient models in traffic and travel demand forecasting
		3.2	Develop Hybrid Intelligence for Meta-Modelling
		3.3	Data driven auto-calibration of simulation models for Digital Twin application
4	AI-powered seamless integrated multimodal traffic management	4.1	Stress test scenarios generator
		4.2	Towards seamless traffic management strategies
		4.3	Abstracting traffic management actions for model free AI-assisted decision making
		4.4	Multimodal management orchestrator
5	ACUMEN Digital Twin integration	5.1	Definition of the ACUMEN Digital Twins Architectures
		5.2	Integration of ACUMEN AI-Aided Management and Decision Tools
		5.3	Integration of Mobility Models and Simulation for ACUMEN Pilots
		5.4	Development of the Generic ACUMEN Digital Twin Tool
6	Pilots and demonstrators	6.1	Collect technical and scenario specifications of pilots' data and models
		6.2	Innovative holistic mobility platform
		6.3	Seamless mobility management via demand incentives with AI-powered multimodal data fusion and estimation
		6.4	Day-to-day planning for traffic restrictions and penalising strategy with AI-powered travel

			demand and traffic prediction models
		6.5	Seamless on-demand door-to-hub mobility optimisation
		6.6	Pilot coordination and results synthesis

Table 1-5 The pilot connections to other WPs and tasks

	Task	Pilot 1 Athens		Pilot 2 Helsinki		Pilot 3 Amsterdam		Pilot 4 Luxembourg	
		Input	Validate	Input	Validate	Input	Validate	Input	Validate
WP2	Task 2.1			✓	✓				
	Task 2.2	✓		✓	✓			✓	
	Task 2.3	✓	✓	✓	✓				✓
WP3	Task 3.1		✓					✓	
	Task 3.2		✓						
	Task 3.3	✓	✓		✓		✓		
WP4	Task 4.1	✓					✓		✓
	Task 4.2			✓	✓	✓	✓		✓
	Task 4.3		✓	✓					
	Task 4.4						✓		
WP5	Task 5.1	✓		✓		✓		✓	
	Task 5.2	✓		✓		✓		✓	
	Task 5.3			✓		✓		✓	
	Task 5.4		✓		✓		✓		✓
WP6	Task 6.1	✓		✓		✓		✓	
	Task 6.2	✓							
	Task 6.3			✓					
	Task 6.4					✓			
	Task 6.5							✓	
	Task 6.6	✓		✓		✓		✓	

2. Athens pilot (Task 6.2)

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Partners involved

Partner	The role in this pilot
DAEM	Pilot leader
NTUA	Scientific advisor of the pilot, transport simulation model owner
HERE	Provision of HERE Speed and Probe Data
MOBL	Multimodal vehicle trajectory collection using a swarm of drones
AIMSUN	Simulation Platform

Timeline

The Pilot is executed in three Phases: in Phase I, DAEM and NTUA will co-design the functionalities and requirements for the ACUMEN multimodal traffic management platform, provide the requirements for the DT and at a latter phase an integration of advanced modelling and simulation capabilities will be executed into a digital twin for Athens. The new systems' architecture will be showcased to the local stakeholders to evaluate its usefulness. In Phase II, NTUA with the help of AIMSUN and UGE will integrate to the ACUMEN platform, developed by the technical partners, the unexpected events identifier (T2.3), Hybrid Intelligence traffic and demand forecasting module (T3.1 and T3.2), the simulation auto-calibration tool (T3.3) and the AI-assisted traffic management module (T4.3). In Phase III, the augmented digital twin will be evaluated in different traffic management scenarios generated within Task 4.1 of the ACUMEN project. The scenarios span from typical to extreme situations and aim to examine ACUMEN solutions impacts on i) system performance, ii) efficiency, iii) safety, and iv) environment. The results are to be fed in T6.6. Such an integration is expected to take place in two-stages, allowing for a complete multi-faceted evaluation and fine-tuning of the proposed solution.

Figure 2.1: Athens pilot phases

More specifically, a detailed timeline for the Athens pilot is presented in Figure 2.2 below covering the whole official duration of the pilot from December 2023 until March 2026:

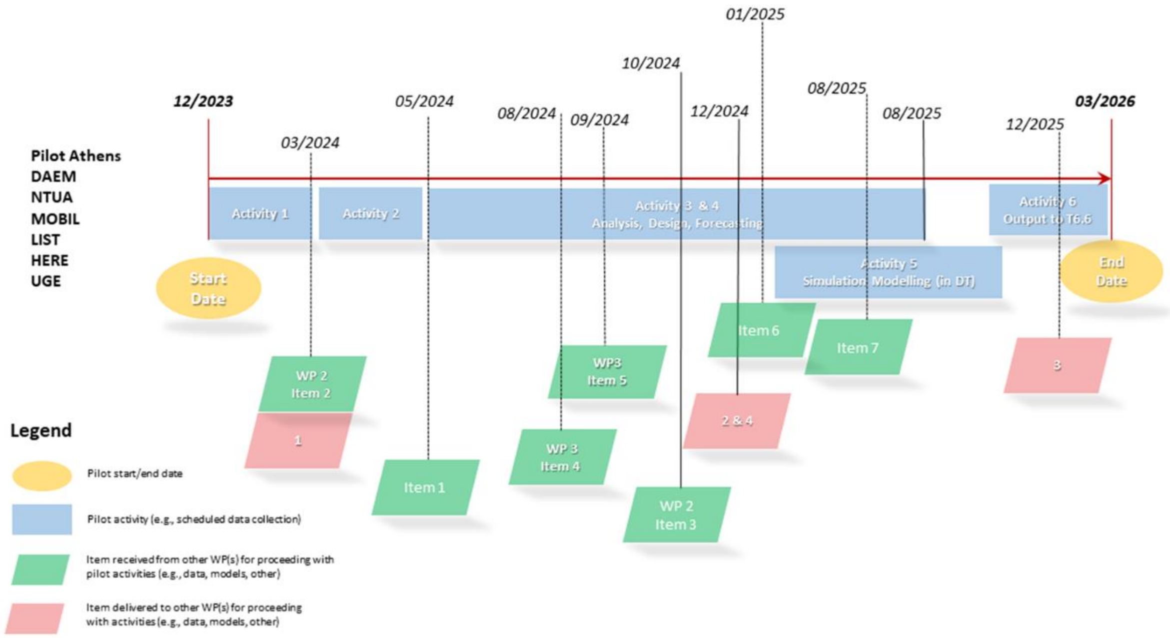

Figure 2.2: Athens pilot timeline.

In the following Tables, the “Activities”, “Input Items”, and “Output Items” are presented.

Table 2-1 Activities

Activity	Description	Planned period	Status
1	Describe scenarios to be tested, define area of interest, data collection from already available data sources, drone experiment design	12/2023 - 3/2024	Completed
2	Data collection from drones	3/2024 - 5/2024	Completed
3	Analysis of collected data Evaluation of the functionalities of the already existing Athens DT	5/2024 - 8/2025	Ongoing

	HERE data analysis and data processing		
4	Modelling: Hybrid Intelligence traffic and demand forecasting module [Tasks 3.1 and 3.2] Unexpected events identifier [Task 2.3] Simulation auto-calibration tool [Task 3.3] AI-assisted traffic management module [Task 4.3]	5/2024 - 8/2025	Ongoing
5	Integration of modules into the digital twin	2/2025 - 10/2025	Not started yet
6	Test scenarios through the digital twin – Evaluation on the basis of system performance, safety, and environmental impacts	9/2025 - 3/2026	Not started yet

Table 2-2 Athens pilot Input Items

Input	Description
1	Drone data collection
3	WP2: Unexpected events identifier [Task 2.3]
4	WP3: Hybrid Intelligence traffic and demand forecasting tool [Task 3.1, Task 3.2]
5	WP3: Simulation auto-calibration tool [Task 3.3]
6	WP2-4: Validation and evaluation ACUMEN data platform
7	WP2-5: Initial platform for testing in pilot M18
8	Data from partners NTUA, MOBIL, HERE

Table 2-3 Athens pilot Output Items

Output	Description
1	WPs2-5 user requirements for the development of the technical tools in the context of the Athens pilot (Specifications according to Milestone on M12)
3	Pilot results

From M12 until M15 the launch of the pilot includes, additionally to the preparatory activities like the formulation of scenarios to be tested, the definition of the area of interest for the pilot execution, the collection of data from data sources that are already available and the design and specifications for the drone experiment.

In the period of M15-M17 the drone experiment is planned to take place in the selected Athens area for on-field data collection of vehicle trajectories.

Then from M17 until M32 the main implementation and activities of the Athens pilot will take place. These will include diverse tasks as described at the objectives of the pilot such as the analysis of collected data from the drone experiment, the data analysis and data processing by HERE, as well as other tasks such as the evaluation of the functionalities of the Athens DT. In parallel, technical tasks will be active that refer to:

1. Providing input to the multisource data fusion (analytics) module (Task 2.2)
2. Providing input and evaluating the identifier of unexpected events module (Task 2.3)
3. Providing input and evaluating the Hybrid Intelligence traffic and demand forecasting module (Task 3.1-3.2)
4. Providing input and evaluating the simulation auto-calibration tool (Task 3.3)
5. Providing input and evaluating the AI-assisted decision making (traffic management) module (Task 4.3)

Also, it is foreseen to integrate the multimodal platform developed with the Athens Digital Twin to provide a visualisation environment of the outputs of the different modules. The ACUMEN digital twin's will provide a common data repository for digital users to upload, download and browse data set according to access rules that will be defined in a later stage. It will also provide access to the list of scenarios. Users of digital twin can choose a scenario to be visualized in the 2D tool. The ACUMEN will allow 2D visualizations of the simulation, link/route/ region-based information, and 3d visualization depending on the discussion with DUET component owner. Also LIST is developing the 3D visualization for the project that can be also used for Athens. These developments will be used to evaluate data and models and of the performed what-if scenarios to support policy formulation.

After the integration of the Digital Twin, the testing of scenarios through the DT is planned to take place to evaluate the ACUMEN overall framework in terms of system performance, safety and environmental impact for the policy simulations, as also analysed above.

2.1. Pilot scenario description

In the framework of the Athens pilot, Machine Learning (ML) and Artificial Intelligence (AI) methods, aim to create a multi-scale, multi-horizon, and multi-modal traffic prediction system. The main aspect is the integration of an AI-powered visualisation tool and Decision Support System (DSS) into the ACUMEN digital twin. This strategic integration forms the backbone of a seamlessly integrated and interactive traffic management framework.

In the Athens pilot, DAEM, as the pilot leader, is in charge of providing the requirements and functionalities of the city of Athens perspective for the development of the comprehensive mobility platform that collects multimodal data from different sources and provides traffic and transport analysis, short-term forecasts, and a simulation tool. DAEM will contribute to the integration into a Digital Twin for Athens. The platform is expected to provide an innovative tool for traffic analysis and forecasting. DAEM will also provide any existing available city data as well as mainly contribute to the involvement of local stakeholders to demonstrate the applicability of the platform, evaluate its usability and assess its potential.

NTUA serves as the scientific advisor and owner of the transport simulation model. NTUA's key role involves contributing to the development of a simulation and decision-making tool tailored for the Metropolitan Area of Athens. NTUA alongside DAEM will actively participate in the integration process, ensuring the seamless inclusion of the simulation model into a Digital Twin. Additionally, NTUA takes on responsibilities in the initial stages of the project, involving tasks such as data processing and the development of ML and AI models.

MOBL provided multimodal trajectory data so that the simulation tool is being calibrated more accurately. In particular, a swarm of drones are used to gather the trajectory data as they flew over important areas of the network that are either currently not being monitored by other sensors or, even if they are, more data was needed. Emphasis was given on on-street parking and delivery vehicles. As the Athens pilot proceeded, the exact location of the monitoring location of the drones was determined (see timeline above). This location was agreed by the different partners involved in the Athens pilot. The drone flights took place in mid-2024 to avoid phenomena of seasonality in traffic patterns (Easter and/or summer holidays) and in order to have favourable weather and lighting conditions.

Lastly, HERE will provide traffic data and technical support for integration of the data into the simulation model.

Aims and objectives.

The main goal of the pilot is to design, implement, and test an innovative holistic mobility platform with the capability to provide transport/traffic analytics, make multimodal short-term traffic predictions (private car and public transport), and provide a simulation/decision making tool for the transport authorities. This will be integrated into the Athens Digital Twin and is expected to provide a powerful tool for traffic analysis and prediction for the Traffic Management Centre of the Region of Attica. More precisely the objectives of the Athens pilot are:

1. The development of an innovative platform with the ability to provide: i) real-time traffic-related analytics (in the form of quantified KPIs), ii) traffic forecasting for passenger cars and transit and identification of critical bottlenecks, iii) optimal traffic management strategies towards optimising the traffic flow conditions (e.g., minimisation of queues, reduction of delays, etc.) (contributing to the overall project objectives O1, O3 and, O4)
2. The development and evaluation of advanced data governance and data exchange models and hybrid intelligence schemes (contributing to the overall project objectives O2 and, O5).
3. The use of benchmarking techniques to guarantee the transferability of the solution implemented and tested in the Athens Pilot to other sites (contributing to the overall project objective O6)

Pilot site description

The pilot's site is the Athens Metropolitan area, with a population of 3 million people, that includes 58 municipalities out of which City of Athens is the largest one. The pilot will consider private cars, trucks, and public transport. The region currently grapples with congested arterials and motorways, enduring queues at critical signalised intersections, extended travel times for entry into the city centre, and the pervasive issue of illegal parking causing disruptive delays along signalised sections. Augmenting these challenges is a notable absence of data governance models, hindering effective coordination and decision-making. A lack of a Common Operational Picture (COP) for traffic management further exacerbates the situation, contributing to suboptimal responses to dynamic traffic conditions. Moreover, there exists a significant gap in cooperation between relevant authorities, resulting in services that operate without a comprehensive understanding or optimization within the broader urban mobility system. Compounding these issues is a disconnect between key players, including Transportation Network Companies (TNCs), public transit agencies, and Traffic Management Centres (TMCs). This lack of coordination not only hampers efficiency but also contributes to outdated demand estimates and mode choice models, making it challenging to predict and plan effectively. In this complicated urban picture, international comparisons are also missing, and there is no benchmarking for international comparison.

Pilot scenario description

The pilot scenarios are designed to involve end-users from various stakeholders in the Athens traffic ecosystem, including the Ministry of Transport, public transportation companies, and city officials. The ACUMEN framework will undergo testing in forecasting simulations that predict traffic changes within the City of Athens, providing anticipated outcomes. Consequently, the evaluation will focus on assessing the support ACUMEN provides in the policymaking process. The above-mentioned scenarios aim to demonstrate the efficiency of the developed multi-scale, multi-horizon, and multi-modal prediction framework and demonstrate the efficiency of the proposed Traffic Management Strategies by the AI-powered visualisation tool and DSS in local and network-wide scales.

2.2. Summary and Analysis of Data Collected to Date

This section includes the activities that took place so far in the Athens pilot referring to data collection.

The main activity that took place was the drones' experiment for data collection in 9 locations in the centre of Athens. The experiment was coordinated among MOBIL, DAEM and NTUA. The data collection in Athens was conducted using 8 drones across 9 different locations over a period of 5 working days, capturing data during the morning (7:00-10:00) and afternoon (15:00-17:00) peak hours. The total volume of the video data gathered amounts to ~6TB. At the time writing this deliverable (October 2024), MOBIL team has completed the extraction of trajectories for all days and drones (5 days, 8 drones, csv files, ~48GB) from the Athens experiment that will allow the better calibration of the NTUA model. A sample of these trajectories (1 day, 8 drones, csv files, ~12GB) had already been sent to NTUA back in September 2024 for feedback, to initiate their development work and avoid any potential bottlenecks due to the large volume of data. It should be noted that MOBIL team will keep supporting the team of NTUA in handling the drone data, extracting the necessary inputs for the model development, additional analyses and treating any issues that might arise. Thus, preliminary insights and first results are expected to be derived in the forthcoming period.

More specifically, for the drones experiment, the 8 drones mapped 9 important locations were identified in the centre of Athens as presented in the figures and descriptions below. Each location includes a map on the targeted area that the drones covered, as well as a photo of aerial view from the drone.

D1 – Omonoia square of Athens, a location with vast traffic congestion and monitoring on traffic as well as taxi stands.

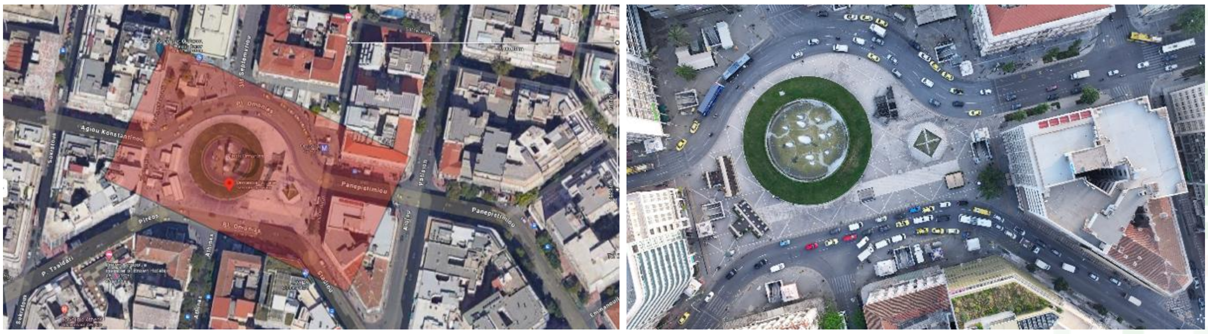

Figure 2.3 Map of the drone location D1 and aerial photo from the drone

D2 – Varvakeios area where an underground parking facility of the city operated by DAEM is located and it is an area where a major commercial market is operating. Hence the drone targeted the local traffic and the traffic entering and exiting the parking.

Figure 2.4 Map of the drone location D2 and aerial photo from the drone

D3 – Klauthmonos square, as area where the second underground parking facility of the city operated by DAEM is located. Also, the square neighbours a large avenue of Athens, Stadiou street with traffic congestion. The drone targeted the Stadiou street traffic for a small part of the avenue and the traffic entering and exiting the parking.

Figure 2.5 Map of the drone location D3 and aerial photo from the drone

D4 – Panepistimiou street is a large avenue of the city including bus stops, metro station and many short-term taxi parking.

Figure 2.6 Map of the drone location D4 and aerial photo from the drone

D5 – Akadimias street, another large avenue of the city with many bus stops and traffic congestion

Figure 2.7 Map of the drone location D5 and aerial photo from the drone

D6 – Syntagma square, main crossroad of avenues neighbouring the Parliament and main Athens square to collect data on traffic and traffic lights.

Figure 2.8 Map of the drone location D6 and aerial photo from the drone

D7 – Amalias avenue, is neighbouring with D6 with similar characteristics as well as congestion due to touristic tour operators, buses and taxis short parking. The start of Ermou pedestrian street is also located the main commercial area of Athens.

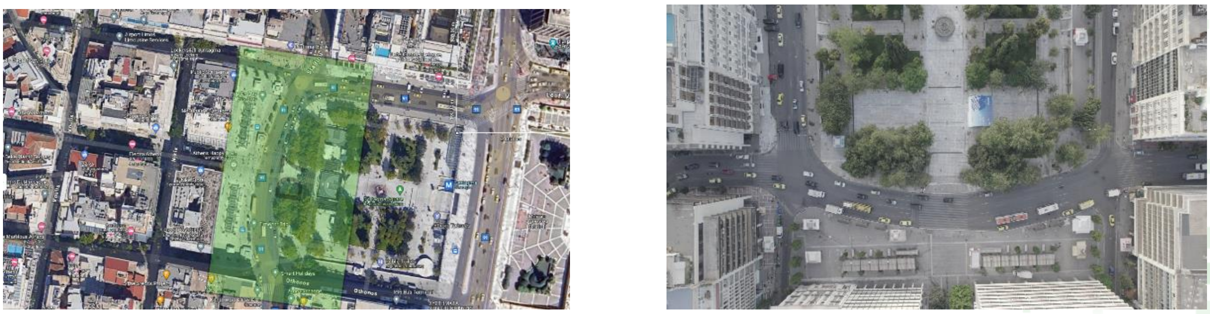

Figure 2.9 Map of the drone location D7 and aerial photo from the drone

D8a – Amalias avenue, an area where the pedestrian route for the Parthenon and the Acropolis Museum starts. The area invites a large number of touristic buses and tour operators, as well as taxis with high traffic characteristics.

Figure 2.10 Map of the drone location D8a and aerial photo from the drone

D8b – Vas. Konstantinou avenue passing from a major historical attraction, Kallimarmaro Stadium, a location with traffic congestion and touristic vehicles and taxis flow.

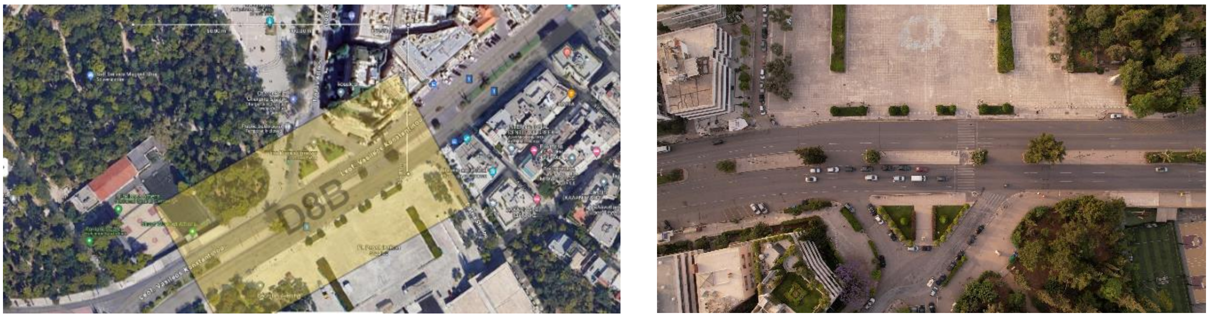

Figure 2.11 Map of the drone location D8b and aerial photo from the drone

In addition, data were requested and already provided by HERE, including the mean speed at the road section of the network of Athens, as well as vehicle trajectories at selected critical intersections. The latter will be combined with the loop detector data already owned by NTUA. In Figure 2.12, a map of the road network, the selected intersections and the locations of the detectors is provided.

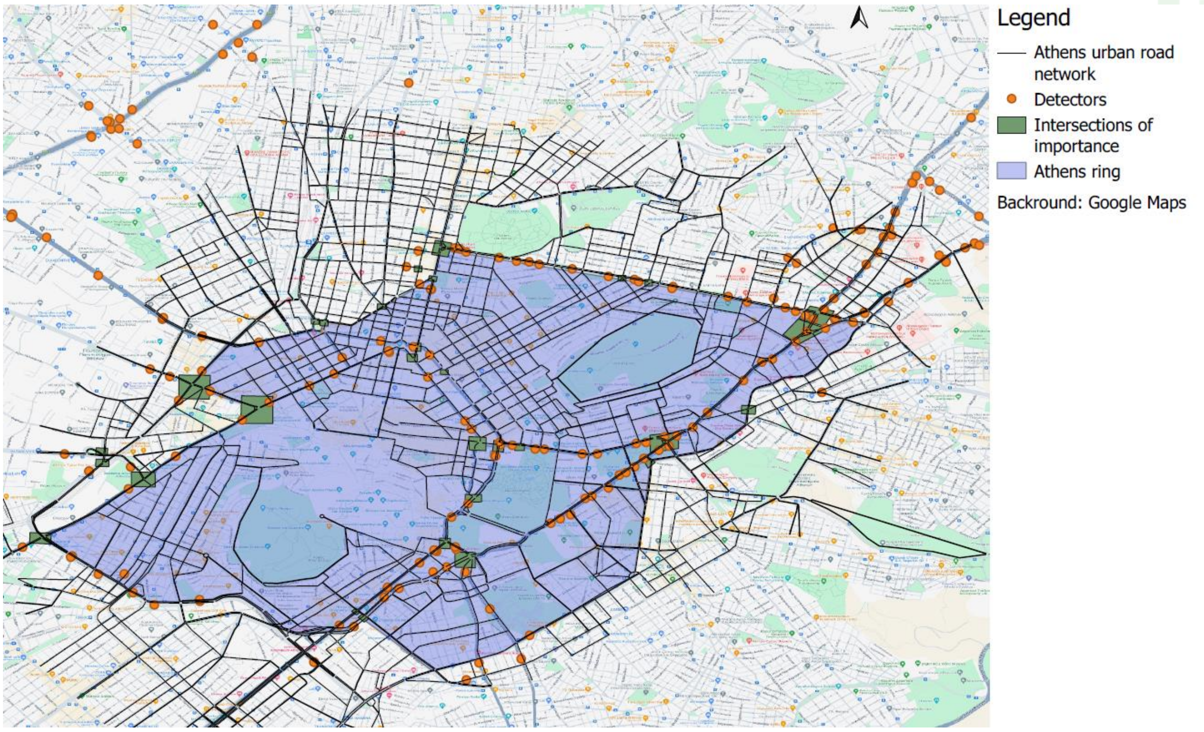

Figure 2.12 Map of Athens Road network along with locations of loop detectors and critical intersections

Hence the general categories to be researched in the use case scenarios and to be monitored by the traffic models are related to:

- traffic congestion in major crossroads,
- traffic lights timing and routing delays,
- areas of touristic vehicles long and short-term parking,
- areas of taxi stand,
- traffic on and off closed parking facilities,
- roadworks etc.

2.3. Progress of Model Development

Regarding the model development, its modules are currently under progress by NTUA. More specifically, the progress of each module is described below:

- For the unexpected events identifier that is related to T2.3, the methodological approach has already been identified and some initial results were retrieved and analysed in line with milestone MS7.
- The initial versions of the Traffic Forecasting models are already developed, and the validation process is currently ongoing. The module is related to T3.1 and T3.2.
- Regarding the module of simulation auto-calibration of T3.3, all data are shared with UGE, namely the Athens Testbed detectors and the dataset of HERE, and the methodology is currently under development.
- The methodology of AI-assisted traffic management of T4.3 is under development.

All final versions of the modules are to be finalised according to the project timeline. Finally, the drones experiment data analysis and integration pipeline are under discussion with UGE for integration in T3.3. For the Athens modelling/simulation, Sumo and MnMs are used.

Initial Specifications of Unexpected events identifier

The core concept of this proposed method is to calculate the expected average weekday speed and volume time series, which represent the anticipated traffic behaviour at a specific loop detector within the network. This expected data is then compared with real-time data captured at the same location using clustering techniques. Significant deviations from the expected traffic values will be identified as non-recurrent events, likely caused by unexpected incidents. The proposed methodology is divided into two main components, which are briefly outlined below.

The first component focuses on calculating the expected average daily time series of speed and traffic volume at each specific location (loop detector), capturing typical daily traffic fluctuations. To achieve this, an LSTM-based Autoencoder is initially used to filter out non-recurrent events from historical traffic data, ensuring that only typical measurements are considered for estimating the daily pattern. Once the expected average speed and volume time series for a location are established, the raw historical data, without any preprocessing, are input into the component to measure deviations from the expected patterns. These deviations are then passed to the second component of the methodology, the clustering module. This approach enables the clear identification of severe congestion points and the distinction between non-recurrent events and regular traffic congestion.

Initial Specifications of Forecasting Models

Within the framework of Athens pilot, forecasting models developed in WP3 will be tested. The main characteristics of the specific models is that they focus equally on performance and trustworthiness. More specifically, causality aspects will be incorporated, exploiting concepts of Granger causality. Also, traffic theory aspects will be incorporated, following a Physics-Informed Neural Network approach.

Causality is an important property for any prediction model, as it is related with its generalizability. For the purposes of ACUMEN, a Deep Learning adaptation of classic Granger causality is used, namely the Neural Granger. In simple words, to detect causally related time series, an LSTM is used for simulating the relation between the target time series and the other time series

As far as it concerns the theory informed forecasting model, a custom loss is used to train the model, which includes the MSE (= distance from actual measurement) and the distance from fundamental diagram and is compatible with any deep learning model.

By Including aspects of traffic flow theory and causality, we aim to increase the model's trustworthiness and accuracy.

2.4. Other activities and Achievement

There are no other activities to report apart from the Athens pilot as it is formulated so far.

2.5. Alignment with Timeline

The progress so far is aligned with the timeline depicted in Figure 2.2.

3. Helsinki pilot (Task 6.3)

Contact list & Partners involved

Contact list

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Partners involved

Partner	The role in this pilot
FVH	Pilot leader
MOBL	Multimodal vehicle trajectory collection using a swarm of drones
HERE	Provision of Speed and Probe Data
AALTO	Developing the concept and preparing tools for assessment of data
AIM	Developing a mobility model for the pilot area

Timeline

This chapter describes a timeline of the ACUMEN project, divided into three phases. Each phase is characterized by pivotal activities that contribute to the progression and refinement of the Helsinki Mobility Digital Twin instantiation.

There have been a few adjustments in the timeline from D6.1, which are reflected in Figures 3.1 to 3.3 and Table 3.1. In specific, the following adjustments have been made.

Timeline for Activity 1 adjusted

As the 1st drone flight sessions were done in 9/2023, the timing for the 2nd and 3rd drone collections has been updated as follows.

- 2nd Drone data collection updated on the timeline 9/2024
- 3rd Drone data collection updated on the timeline 9/2025

Timeline for Activity 6 adjusted

- The Digital Twin, simulation, and tool integration will initially focus on a demonstration from 10/2024 to 01/2025 with minimal integration on the 2nd version of the WP5 Digital Twin. However, the Digital Twin/simulation continues in Activity 8.

Timeline for Activity 7 adjusted

- The approach in Activity 7 has been divided into three parts to better align with the plan: 7.1, 7.2, and 7.3, which incorporate real-world validation, simulation, and analysis for robust system development.

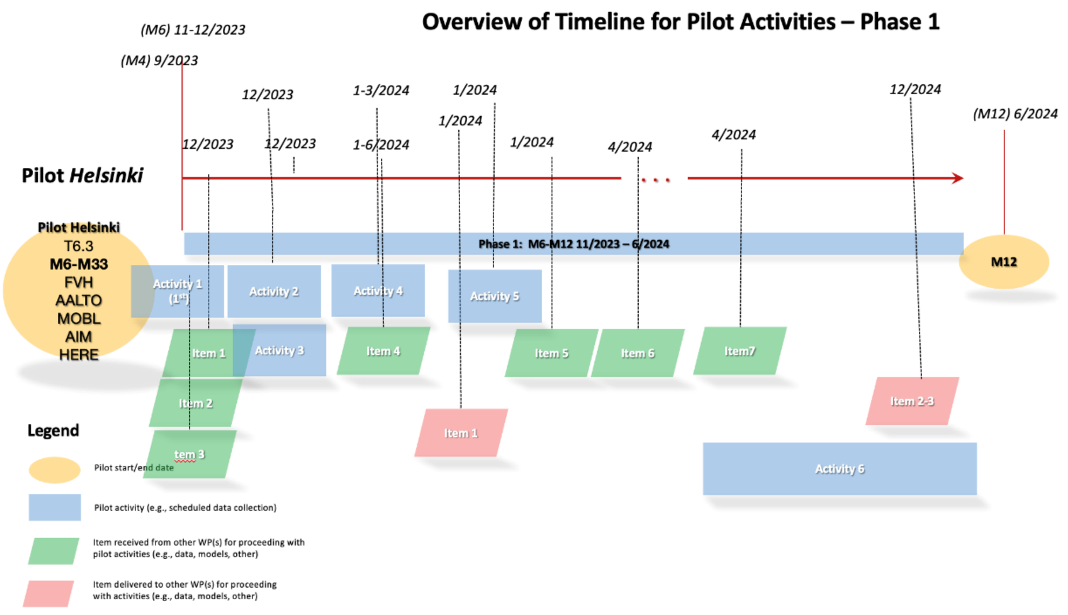

Figure 3.1: Helsinki Timeline Phase 1 – updated from D6.1

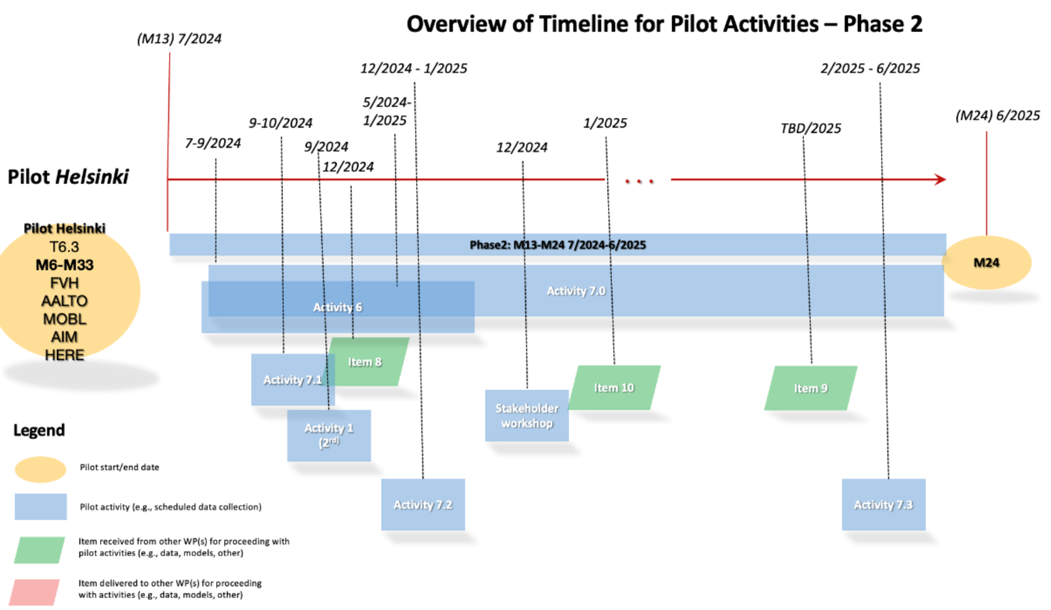

Figure 3.2: Helsinki Timeline Phase 2 - updated from D6.1

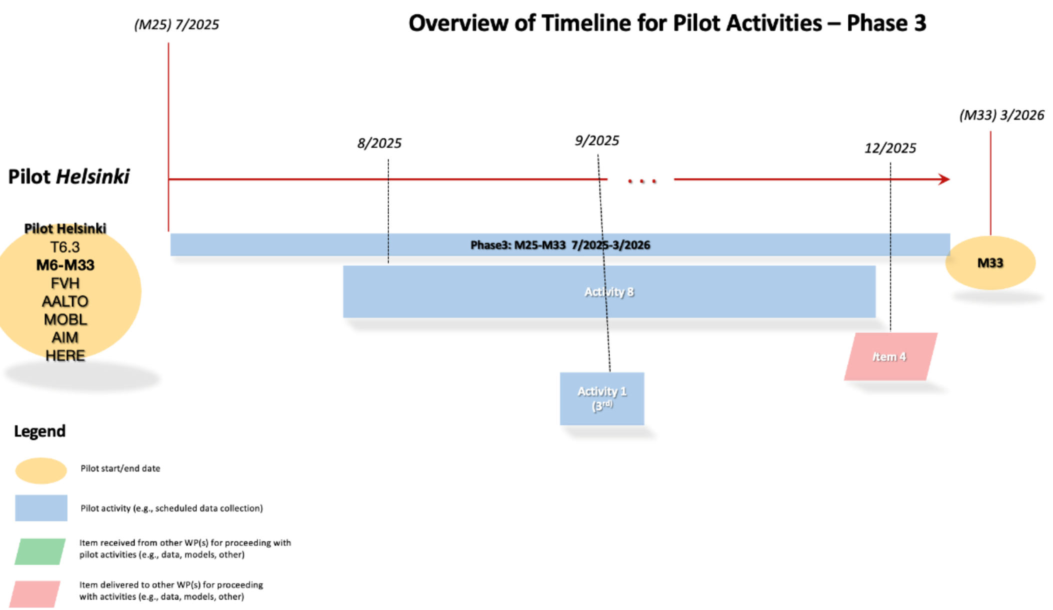

Figure 3.3: Helsinki Timeline Phase 3 – updated from D6.1

Table 3-1 Helsinki pilot activities

Activity	Description
1	Sept 2023 – 1st Drone flights and data collection - *completed* Sept 2024 – 2nd Drone flights and data collection - *completed* Sept 2025 – 3rd Drone flights and data collection – *designed and planned*
2	Adapt pilot scenario - Reflecting the setup of the Mobility Helsinki Digital Twin concept, which utilizes datasets from traffic, infrastructure, and conditions, alongside the instantiation of the Helsinki Digital Twin as a digital replication of the city. This activity includes sharing available datasets for models and ACUMEN DT, as well as defining the data collection phases. - Pilot summary and inputs from management scenarios developed within WP4's framework to support real-life implementation.
3	Data Collection -Update data collection in pilot summary (in connection with WP2). -Determine if travel sense data collected by the HSL app and inform T2.1. -Determine the relevant data sources for the simulation scope. -Identify the data sources that need to be generated through the Data pre-processing.
4	**Data Pre-processing:** -Feed information to T2.2. -Exchange determined data protocols. -Identify and apply data fusion and estimations via AI techniques to combine data from multiple sources. -Include HERE data and support for data processing.
5	**Model Selection and simulation** -Select a simulation model based on the objectives and integrated data. -Build models for Baseline and impact analysis. -Build a simulation environment and the digital twin
6	**The Digital Twin, simulation and tools integration**
7	**Test tools**
7.1	- Mobile app pilot 9.-10.2024 - The real-world activities in September 2024
7.2	-Test data fusion, estimation and AI-tools with the simulation tool. - Run the simulation for each management (WP4) defined scenario, (1st demo version)
7.3	- Analyse the results to gain insights into the system's and tools behaviour under different conditions.
8	**The overall ACUMEN methodology and holistic assessment.** -Monitor network-level traffic changes using classical data sources and drone-collected data, to measure intervention effectiveness and simulation calibration in Digital Twin tools and modules. -Revise the process of data acquisition involving T2.2, T2.3, and T4.3 tasks. -Analyse the simulation outputs and analyse the potential impact using AIM's simulation tool. -Interpret the results to T6.6.

Table 3-2 Helsinki pilot input

Input	Description
1	Updates for the management scenarios in WP4 (T4.2)
2	Data collection for management (T4.3) and Secure and privacy scenario (T2.1)
3	Simulation models based on management scenarios (T4.3)
4	Data fusion, estimations, and AI techniques to combine data from multiple sources (T2.2)
5	Simulation model based on the objectives and integrated data. a) Baseline and b) Impact analysis (T4.3)
6	Tools delivery, setup, and support during the first pilot test (T2.2)
7	Unexpected pattern identifier tool (T2.3)
8	ACUMEN DT instance for Helsinki pilot (T5.4)

Table 3-3 Helsinki pilot output

Output	Description
1	WPs 2-4 user requirements for the development of the methodological tools in the context of the Helsinki pilot
2	Provide requirements for ACUMEN Digital Twin (WP5)
3	Pilot result
4	Organization of workshops

3.1. Pilot scenario description

In this pilot, travellers and residents will be offered incentives and nudges for adopting sustainable modes of transportation, including walking, cycling, e-scooter, and utilizing public transport and other sustainable demand-responsive transport services.

Aims and objectives

The primary goal of the Helsinki Pilot is to demonstrate innovative solutions that dynamically influence travellers' mode choices, emphasising sustainability and citizens' well-being. The pilot specifically addresses challenges related to traffic congestion during morning and evening peak hours, particularly the crowdedness of public transport vehicles, by employing soft policies such as nudging and incentivising travellers to encourage them taking other modes over cars and PT. The key focus lies in investigating dynamic traffic to enhance the seamlessness of multi-modal trips. By offering dynamic incentives—such as awarding users of CO_2 points saved compared to car travel—we can influence travel behaviour. This dynamic approach encourages passengers to shift to sustainable modes of transport and choose city bikes or public transport options over private cars. The pilot specifically addresses challenges related to traffic congestion during morning and evening peak hours, particularly the crowding of public transport vehicles, by employing soft policies such as nudging and incentivizing travellers to encourage them taking other modes over cars and PT.

Pilot site description

The project targets a location in the southeast of Jätkäsaari area, where the west harbour terminal of Helsinki is located. Toward the ferry terminal, traffic congestion negatively impacts travel times and convenience, especially during the departure and arrival of ferries.

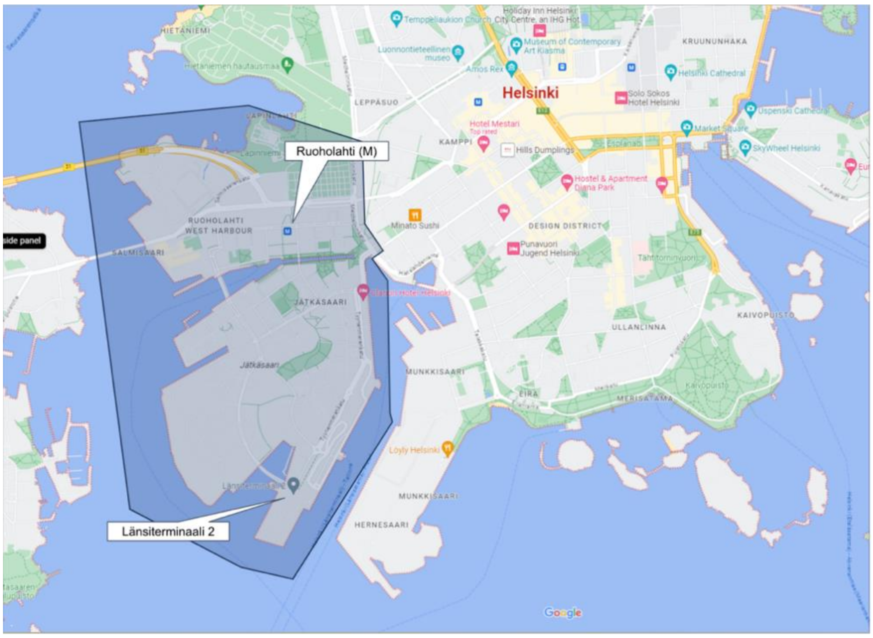

Figure 3.4 Map of pilot site location

The pilot site is facilitated at the Mobility Lab Helsinki - the city's testbed for smart mobility –Mobility Lab Helsinki builds on the foundation built before under the name Jätkäsaari Mobility Lab in 2019-2021, continuing to enable real-world piloting of smart mobility solutions, taking mobility digital twins and the easier and more impactful use of data as it's central focus area.

The project aims to identify the requirements and interfaces crucial for connecting the digital twin ACUMEN, also with existing Helsinki Digital Twins. This digital twin enables seamless integration with analytics and AI-based multimodal management tools.

The challenges associated with traffic in the pilot will be addressed as follows:

1. *Nudges and Incentives*-Strategies to encourage travellers to opt for alternative modes like bikes and public transport

2. *Micromobility*-Exploring the potential use of micromobility solutions, specifically bikes, as viable alternatives during peak hours. Locations of bike stations can be found at https://kartta.hel.fi/link/dbpvt2.

The pilot is targeting test users from target groups. These groups refer to:

1. *Ferry Passengers*-Individuals using the ferry service during morning and evening peak hours.

2. *Jätkäsaari Residents on morning work trips*-Locals commuting from Jätkäsaari to workplaces during morning and evening peak hours.

3. *Jätkäsaari Employees*-Individuals employed in the Jätkäsaari area commuting from/to work during morning and evening peak hours.

Different traveller categories are invited to the Helsinki pilot, such as Jätkäsaari employees, travellers and residents. These travellers are invited to participate in the pilot by downloading a pilot-specific app along with project-specific information about the pilot scope. GDPR compliance for the app is ensured.

There have been different engagement strategies employed for the pilot's purposes. Such strategies refer to media campaigns and selected workshops that have been launched to maintain participant engagement.

An important activity associated with the Helsinki pilot refers to setting up the Traveller app to ensure users a seamless and personalized experience. The pilot-specific Traveller app automatically records participants' transport modes eliminating the need for manual input. The mobile application was launched prior to the initiation of the drone (3 days) activities, and the app continued throughout September and October 2024.

3.2. Analysis of Data Collected to Date

The Helsinki pilot is composed of several tasks and activities that are data dependent. The Helsinki metropolitan area, in general, and the Jätkäsaari port area, specifically, are characterised by diverse data ecosystems. Still, the advanced needs of the ACUMEN project impose the need to collect additional data sources. Different types of data are collected in the Jätkäsaari port area in order to support the development of models as part of the Helsinki pilot's activities described above. This section presents the data collected so far within the pilot, referring, when needed, to the activities planned to exploit such data.

Drone Data

Drone data collection for traffic and transport purposes in Helsinki (WP6) is being conducted by Associated Partner MobiLysis. This data supports methodological work packages (WP2,3,4,5), as for example in developing data fusion schemes and providing detailed input for Aimsun simulation models. Drone data is privacy-friendly and anonymized.

The drone data collection is organised in three sessions aligned with the pilot's phases:

1. 1st Session (September 2023): Video collected, analysed, trajectories delivered.
2. 2nd Session (September 2024): Video collected, analysed, trajectories delivered.
3. 3rd Session: Planned for September 2025.

The 1st and 2nd sessions of data collection are already completed. Processing of vehicular data from the 2nd drone experiment (September 2024) is complete and shared with Helsinki. Pedestrian data from the area where manual counts were conducted are being analysed and expected to be fully delivered during November 2024. The locations of drone data collections are shown in Figure 3.5.

Figure 3.5 September 2024 drone fly areas

The drone data collected include trajectories in terms of detailed vehicle pathways, origin-destination information for comprehensive travel flow, vehicle counts (by type, time, and location).

Regarding some initial insights, the figures below present a preliminary analysis of vehicle trajectory data collected during the initial drone-based data acquisition phase in September 2023 near the harbour area. Analysis reveals a substantial increase in vehicular volume immediately following boat arrivals, observed specifically at 8:15, 9:30, and 15:30. These peaks in traffic support the hypothesis that boat arrivals significantly impact vehicular flow toward the harbour entrance, aligning with the anticipated influx pattern.

Conversely, vehicle arrivals appear more staggered during boat departures, occurring at more distributed intervals—7:30, 9:00, 10:30, and 16:30—suggesting that vehicles reach the port well in advance of scheduled departure times, resulting in a more diffuse traffic pattern.

It should be noted that these results are based on data collected from a single drone monitoring the harbour's entrance and exit. Consequently, broader traffic patterns in the surrounding areas have been excluded from this initial analysis, allowing us to focus solely on port-specific vehicular dynamics. When no arrivals or departures occur, traffic volume remains consistently low, indicating that the port area experiences minimal vehicular flow outside of scheduled maritime activity.

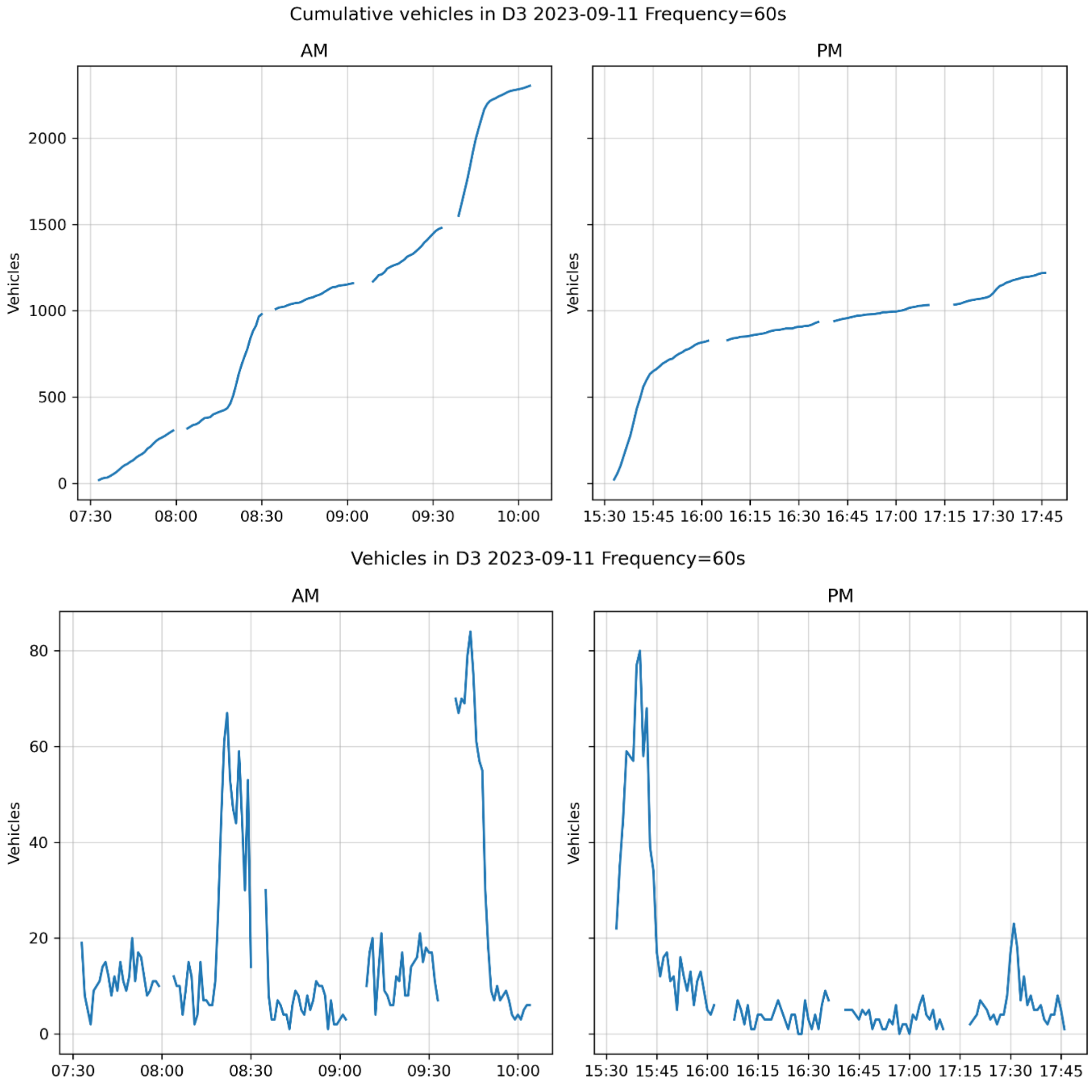

Figure 3.6 Vehicle flows at the entrance/exit of the port

Mobile app data

A mobile app is used for the Helsinki pilot purposes. This app generates data that will be useful for various pilot activities. The collected datasets include data about transportation patterns in Helsinki during September and October 2024. The main GreenImpact feature, which automatically detects modes of transport used by an individual and calculates the CO2 footprint in an anonymized way.
The data is focused on how people move around the city and how this impacts carbon emissions. Screenshots to demonstrate the environment of the app are included in Figure 3.7.

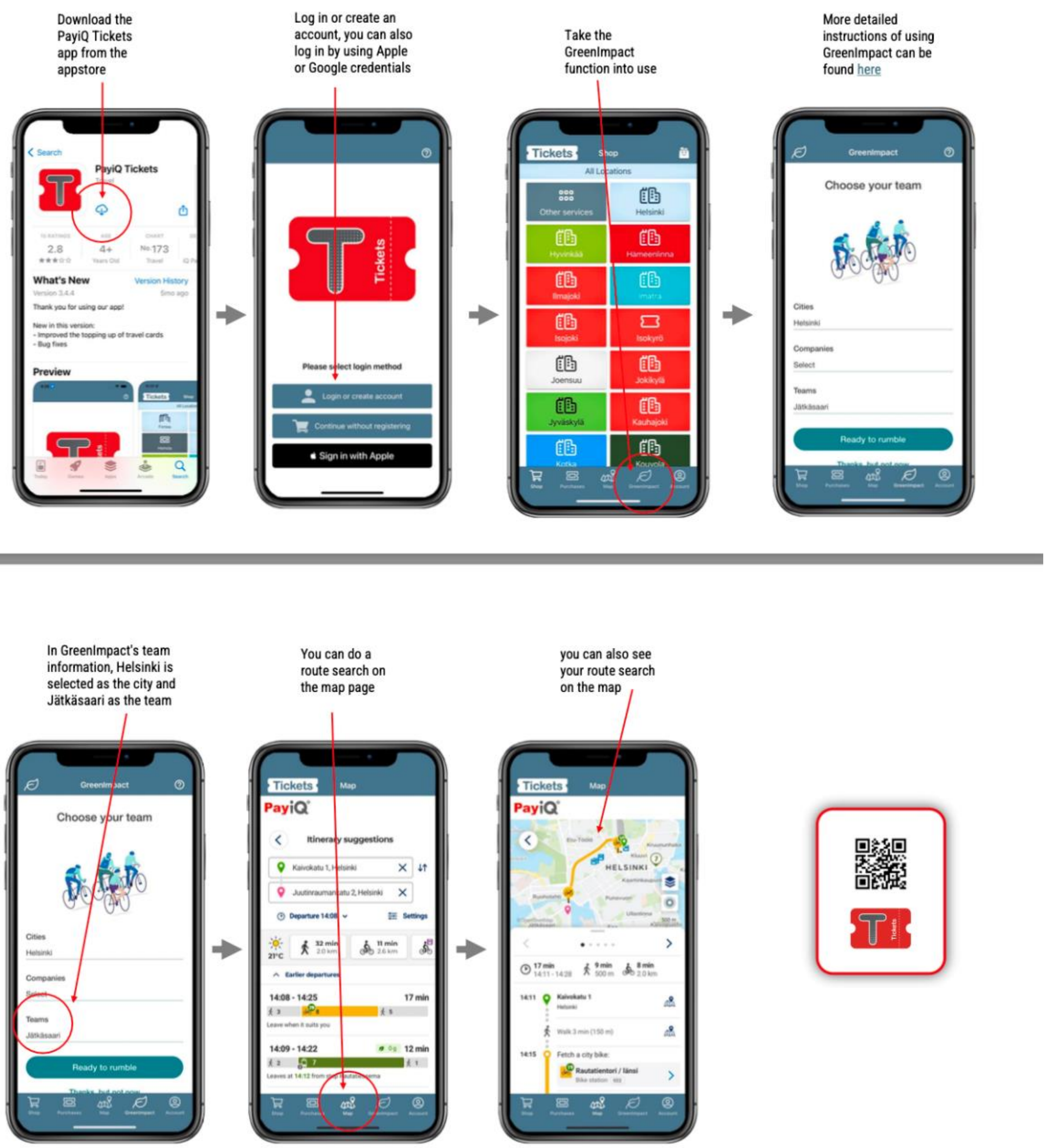

Figure 3.7 PayiQ Tickets app

Through the app, some key information is recorded and will be utilized for the project's purposes. The information that is being tracked by the app refers to:

- *Modes of transportation*: How people get around (e.g., walking, public transport, cycling).

- *Number of trips*: The total number of trips taken using the PayiQ system.
- *Tram stops delays*: How much delays are experienced at specific tram stops.

The user app also generates several reports that are available for usage in ACUMEN via SharePoint (Figure 3.8), including:

- *CO_2 KPI Report*: Shows the carbon footprint of different transportation methods.
- *Mobility Trips KPI Report*: Shows the overall number of trips recorded by each mode.
- *Estimator Report*: Contains a model to predict delays at tram stops, assuming that popular stops have longer delays.
- *Schedule Report*: Provides an extract of the tram schedule used for predictions.
- *Focus Group Data*: Additional data collection from a focus group is underway and will be accessible after October 2024, once the experiment concludes.

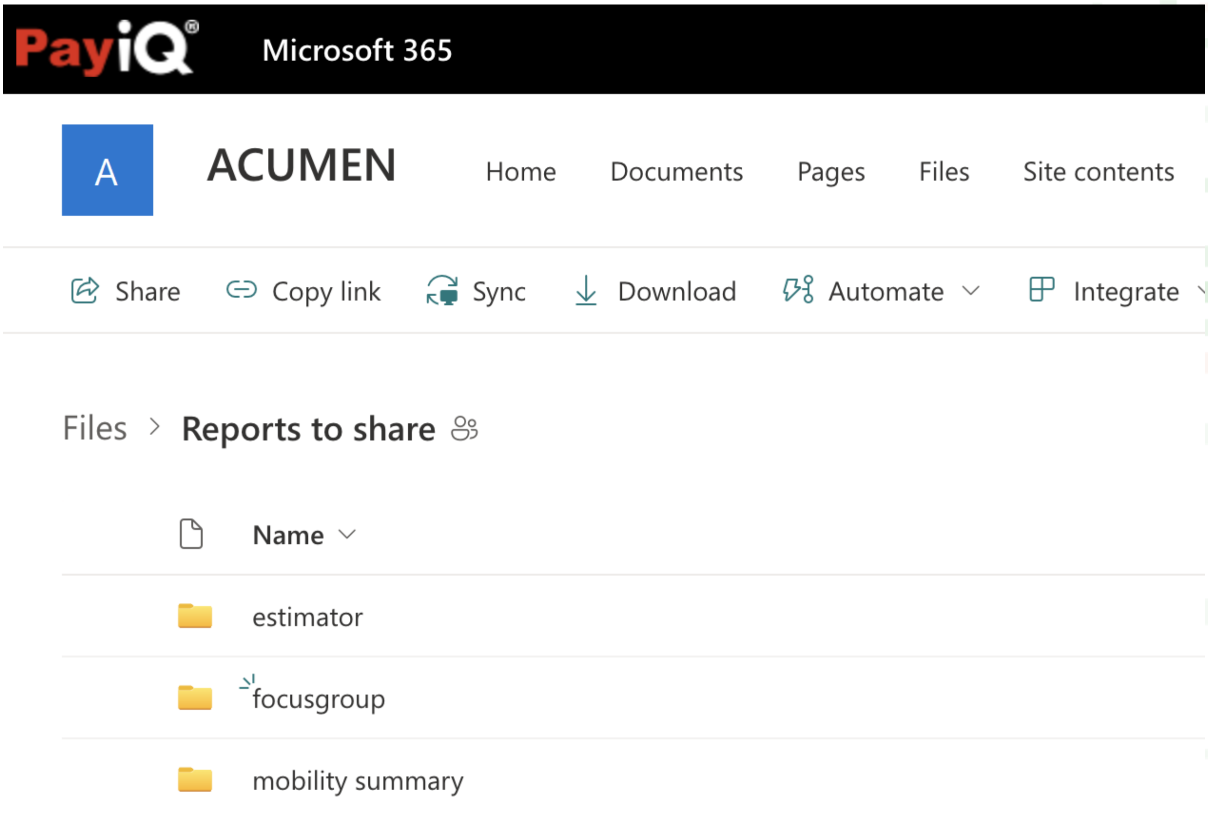

Figure 3.8 Microsoft 365 SharePoint for sharing files

The collected datasets will be partially utilized in WP4, where a methodology is being developed for finding the optimal incentive to promote a seamless multimodal transportation system; and a specific study is underway to support interaction with DT and integrate tool. Overall, this helps to specify traveller User Interface and incentives and nudges, such as offering cinema tickets and accumulating CO_2 points.

The development of mobile app services, as part of the FVH agile piloting program, progressed according to the planned timeline in two phases. However, a key challenge was lower-than-expected participation of test users. Despite promotional efforts through various channels and live events, only 27 out of the targeted 100 users engaged with the app. This shortfall can be attributed to several factors: reduced tourist activity, limited engagement from the Port of Helsinki, challenges experienced by tourists, and the time required for behavioural change.

Despite these challenges, the collected data from the 27 participants will be valuable for analysing mobility patterns, and the tracks of the focus group people 3-5 are under delivery T4.2 The insights gained will contribute to the development of effective traffic management strategies.

Feedback forms will be collected from pilot participants (focus group) and from the residents of Jätkäsaari This input will help optimize incentives, making it more effective in promoting sustainable travel options and enhancing the overall traveller experience.

Bluetooth sensors

Bluetooth sensors are installed by FVH on the tram stops in the Jätkäsaari port area in order to collect passenger counts in the surrounding area (see Figure 3.9 for exact locations). The generated data are further utilized within data fusion models in Task 2.2. The device utilized for data collection refers to Paxcounter, which is an MCU based device for metering passenger flows and multi-sensor data in real-time. It counts how many mobile devices are detected around the area of installation. Paxcounter detects Wi-Fi and Bluetooth signals in the air, focusing on mobile devices by evaluating their MAC addresses. In parallel, it reads and stores data from multiple connected environment sensors.

Defining the incentives requires information about crowding on-board public transport vehicles, which is not directly available at the port area. Combining Bluetooth sensor data, GTFS-RT (real-time transport data), and drone-captured crowding data provides a robust view of both pedestrian and vehicle traffic flows. Bluetooth sensors monitor the harbour entrance and two tram stops, while a fleet of six drones monitors pedestrians and detailed vehicle data and congestion on highway access routes and throughout the pilot area. Together, these data sources enable accurate, real-time estimates of passenger and vehicle congestion at major intersections leading to the highway.

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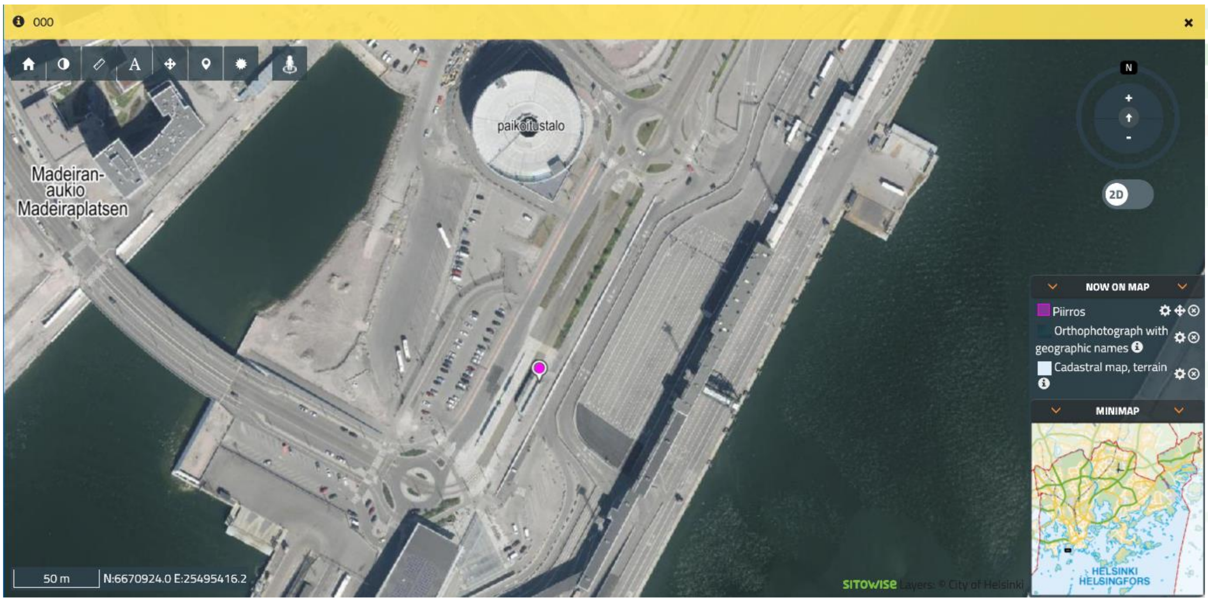


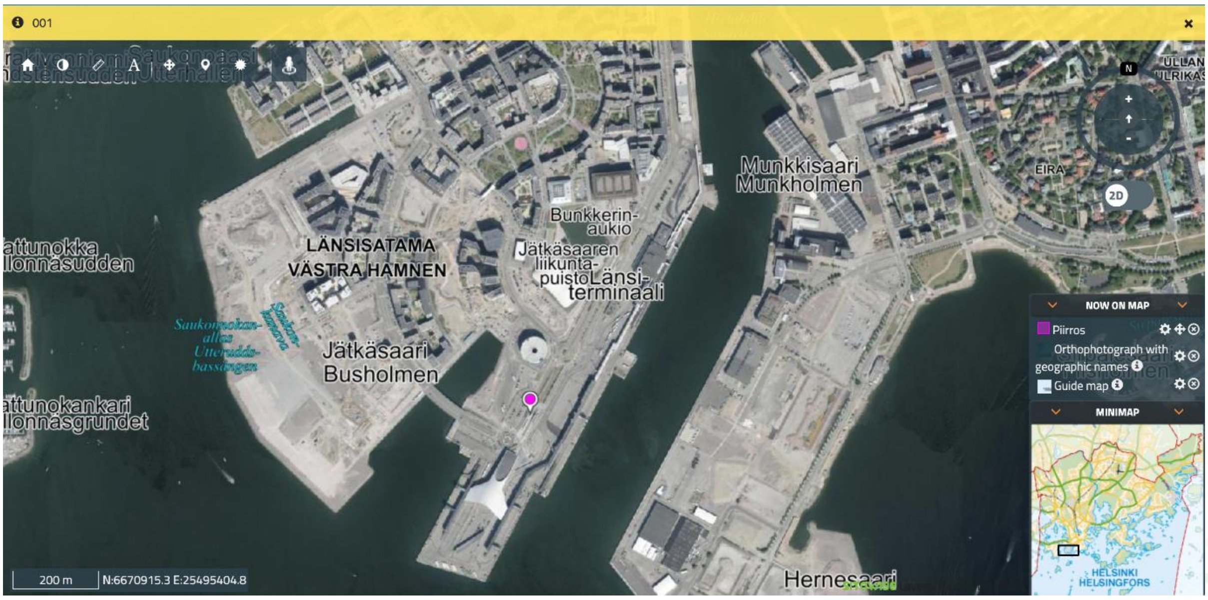


Figure 3.9 Locations of Bluetooth sensors

HERE data

Data collected by HERE is provided to ACUMEN in order to calibrate the Aimsun simulation tool based on the specified administrative areas within the Helsinki pilot. Data are provided for the selected start and end dates, with up to five years of historical data available. In addition to speed data, probe data for junctions are utilized for the Helsinki pilot. A map of the intersections of interest in the Helsinki pilot, covering a total of 25 polygons representing junctions, was also provided to Aimsun in a single GeoJSON file. The probe data for the Helsinki Pilot is available for September 2023, aligning with the timing of the first drone flights.

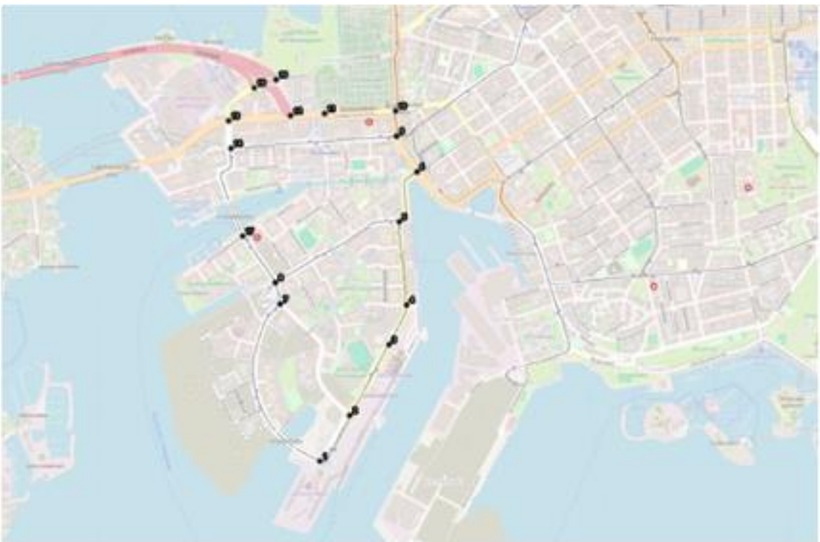
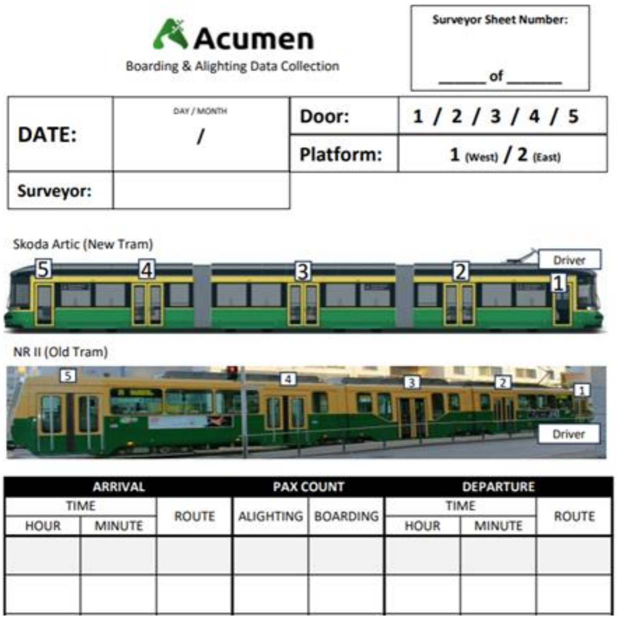


Figure 3.10 Probe Locations

Manual passenger counts

Manual counts have been collected at the Helsinki pilot site on July 16th (during afternoon demand peak due to ferry arrivals) and September 17th. These counts refer to the number of passengers that enter and exit tram vehicles at the pilot area. A data collection sheet (shown in Figure 3.11) was prepared for the data collection process and five people performed the data collection. These data aimed to serve as the ground truth for validating data fusion models developed in Task 2.2. for estimating crowding on-board tram vehicles in the pilot area.


Acumen
Boarding & Alighting Data Collection

Surveyor Sheet Number: ______ of ______

DATE:	DAY / MONTH /	Door:	1 / 2 / 3 / 4 / 5
		Platform:	1 (West) / 2 (East)
Surveyor:			

ARRIVAL			PAX COUNT		DEPARTURE		
TIME		ROUTE	ALIGHTING	BOARDING	TIME		ROUTE
HOUR	MINUTE				HOUR	MINUTE	

Figure 3.11 Manual data collection sheet

3.3. Progress of Model Development

The Helsinki pilot is associated with models that will be developed in the frame of the methodological WPs (i.e., WP 2, 3, 4) and the ACUMEN DT-related WP5. More details about these models are presented as follows.

Data fusion in T2.2 (WP2)

Task 2.2 focuses on developing data fusion methods to estimate tram passenger numbers in Helsinki's Jätkäsaari port area. This information is crucial for understanding crowding levels, which can inform strategies to improve passenger comfort and incentivize sustainable travel choices. The available data sources in the port area do not allow the estimation of crowding on-board tram vehicles, if used individually. Therefore, Task 2.2. is developing data fusion tools to combine both demand-related and operational characteristics associated with public transport in the area in order to generate the required information of how many people board tram vehicles at the stops nearby the ferry station. The fused data sets include Bluetooth counts, GTFS-RT, manual counts, and in the following steps of model development will also incorporate drone passenger counts.

Acknowledging challenges and opportunities associated with each available data set, Task 2.2. develops a modelling framework to fuse these data sets and generate novel information. The developed data fusion framework is based on machine learning tools and methods. The current stage of model development involves expanding beyond linear models and exploring more advanced machine learning techniques (e.g., random forest, bootstrap) to enhance passenger estimation accuracy. This approach aims to leverage the diverse datasets, to create a robust and accurate data fusion model. The output of this model will be the number of passengers that board the tram vehicles that depart from the pilot area's tram stops, hence, leading to expected levels of crowding on-board. The overall framework for data fusion aligns with the initial specifications outlined in Milestone No 3. The models will be finalized by the Task 2.2. completion date, i.e., April 2025.

Unexpected pattern identification in Task 2.3 (WP2)

The model currently being developed in Task 2.3 aims at predicting the future states in the multimodal transportation network and identifying possible anomalies from that. A Dynamic Graph Convolutional Recurrent Neural Network (DGCRNN) model is proposed for this goal, which integrates spatiotemporal graph neural network techniques to model the dynamic interactions among nodes (e.g., train stations) across multiple train lines, which we treat as distinct relations within our graph structure. The model is now able to predict the future 15 minutes' onboard passenger loading data of the commuter train network based on 45 minutes historical data, and the data used for it comes from HSL. Specifically, the dataset includes static GTFS data, automatic passenger count (APC), and automatic vehicle location (AVL) data of the Greater Helsinki commuter train network, covering the period of September 2021. The next step is to integrate other modes in the model in the upcoming year.

Optimal incentives for traffic management in Task 4.2 (WP4)

In Task 4.2, a framework for determining optimal incentives to encourage sustainable travel behaviours is being developed. This task will utilize data from the Helsinki pilot (Task 6.3) to numerically assess the impact of incentivization through a simulation run in Aimsun. The incentivisation scheme includes multimodal aspects.

To support this, Aimsun was provided with Helsinki's existing SUMO model by Aalto. This model was converted by Aimsun for compatibility with their platform. While the imported geometry, demand, and traffic signal data are reasonably accurate, further refinement is necessary. For calibration and validation, Aimsun will integrate additional data sources from the City of Helsinki, HERE, and the drone data collection. The simulation is scheduled for completion by the end of the year.

Calibrating the model according to the new travel costs (calculated as travel time minus incentive) using the app pilot data enables us to investigate the impacts of various incentive schemes on the modal share in the Jatkasaari area by simulating multiple incentive scenarios. Furthermore, the methodology developed in Task 4.2 to determine the optimal incentive for promoting a seamless multimodal transport network will be applied to the Helsinki pilot via the mobile app. This will enable to compare the results of our optimized incentive strategy in WP4 with the currently implemented approach in the app, which awards users 1 point for every 5 kg of CO_2 saved compared to the car travel.

Aimsun simulation

With the Aimsun model, simulations will be conducted using the Aimsun model to visualize network-level comparisons of 'before and after' network conditions. The simulation refers to the whole study area, with a suggested time aggregation that captures traffic characteristics over specific time intervals (e.g., 15 minutes) as well as for the entire simulation period, i.e., the peak hours. Measures such as the average travel time, congestion level, and modal share in a given scenario will be investigated as KPIs. As the model incentivizes specific modes for defined origin-destination (OD) pairs, there are also two cost changes to consider in the network: 1) the travel costs (travel time minus incentive) of various modes between an OD pair before and after the incentive; and 2) the travel time on links/routes for car traffic, due to part of the demand shifting to incentivized modes. The visualization will reflect both of these changes by comparing the scenarios before and after the incentives are applied. A predefined set of routes and OD pairs will be visualised. Current progress of this modelling/simulation approach includes: 1) integration of trajectory data from simulation/ drones; and 2) integration on general simulation KPI.

3.4. Other activities and Achievement

A stakeholder workshop is scheduled for December 3rd, Online workshop on governance and regulatory framework for AI integration into traffic management systems

The Mobile app services
The initial pilot plan to deploy AALTO's TrafficSense, featuring "social" routing recommendations, encountered obstacles that prevented its implementation. Consequently, as the pilot leader, FVH actively sought an alternative mobile app solution to meet the Helsinki pilot's requirements and WP4 management scenarios. The call for mobile app development was carried out through FVH's pilot process, with the aim of identifying a suitable solution for agile piloting. Following this process, PayIQ was selected for experimentation and collaboration in a real-life implementation in Helsinki, where it contributed to the development of services within the ACUMEN Helsinki pilot as part of the Jätkäsaari team. This effort was managed within the ACUMEN project framework, which outlined the reasoning and justification for the mobile application of the ACUMEN Helsinki Pilot. However, the arrangements took longer than anticipated, requiring an adjustment to the timeline accordingly.

3.5. Alignment with Timeline

Main pilot activities

The activities for Task 6.3 are progressing on schedule according to the project timeline. The team has successfully completed the required pilot activities, which include data collection, particularly through drone technology and analysis, the development of pilot specifications (T6.3/T4.2), and the creation of Bluetooth sensors (T6.3)., and data fusion and estimations (T2.2/T…).

Additionally, FVH have established a productive partnership with a new mobile app service provider within a tight timeframe.

FVH has facilitated stakeholder collaboration in the City of Helsinki. A stakeholder WP7 workshop has been organized to gather input and feedback, further enhancing our collaborative efforts. Overall, this initiative is crucial in developing strategies to enhance public transport experiences and promote sustainable mobility choices in the city of Helsinki.
The models T2.2 and T4.2 are currently under development, and the pilot's progress looks promising for the upcoming demonstration.

Digital Twin

Most of the FVH datasets have been uploaded to the initial version of the data management portal as part of the Digital Twin, with the continuing in the new version.

Data Management plan (WP1)

The Helsinki pilot partners have contributed to the development of the ACUMEN Data Management Plan version 1. Updates of data re-used, generated and collected have been added in the second version of this plan, which is due November 2024. The pilot partners will also contribute to the third version of this deliverable with updates that will result from future pilot activities.

Mobile app

Due to (FVH) budget constraints, the mobile app features may not be available during real-life activities in September 2025. Incentives will be shared on info tables, social media, and user workshops.

Last-mile logistics

Last-mile logistics was removed from the Helsinki pilot due to its infeasibility within the scope of the project. Last-mile logistics is a complex issue that requires a separate study and additional resources, particularly for managing sensitive GDPR-compliant door-to-door logistics information.

4. Amsterdam pilot (Task 6.4)

Contact list & Partners involved

Contact list

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Partners involved

Partner	The role in this pilot
AMS	Pilot leader / coordinator / liaison with the City of Amsterdam for the sake of data collection
TUD	Virtual pilot environment development, model calibration, scenario construction and simulation
UGE	Virtual pilot environment development, model calibration
AIM	Virtual pilot environment development, support to transportation modelling
HERE	Network traffic data provision

Timeline

A tentative timeline of the Amsterdam virtual pilot is summarised in the following figures and tables.

A. Timeline Graph

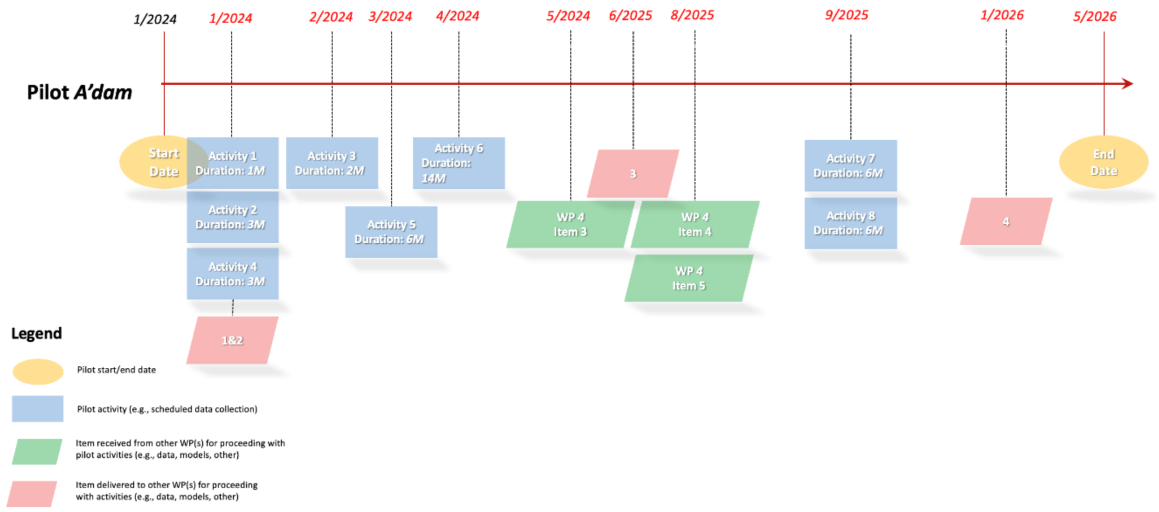

Figure 4.1: Timeline for Amsterdam pilot

Table 4-1: Activities

Activity	Description
1	Form data dictionary of available data sets, structures, frequencies etc.
2	Set-up of a data collection pipeline between Amsterdam TCC and TUD for management data
3	Definition of case study specifics (exact area, exact network, level of detail, …)
4	Simulation model I: aggregated macroscopic dynamics (study: mode choice effects)
5	Simulation model II (MnMs): trip-based macroscopic dynamics (study: mode choice effects, route choice effects)
6	Simulation model III (Aimsun)
7	Virtual pilot validation of seamless-enhanced strategies
8	Virtual pilot validation of orchestration mechanism

Table 4-2 Input items

Item	Description
1	**TUD, UGE, NTUA, UNINA** provide a set of strategies that can help guide the test case design
2	**HERE** will contribute with floating car data, as well as methods and interfaces to process it
3	**UGE** (T4.2) provides seamless management strategies that can be tested in the virtual testbed

4	**UGE** (T3.3) provides support for the virtual testbed calibration
5	**NTUA** (T4.3) provides an AI abstracted strategy to validate on the virtual testbed
6	**TUD** (T4.4) provides the AI orchestration mechanism for validation on the virtual testbed

Table 4-3 Outputs item

Item	Description
1	Management strategies to be developed in the Amsterdam pilot benefit the development of WP4
2	Functional requirements for the ACUMEN DT are delivered to WP5
3	Simulation models and related management strategies are exchanged with WP5 for integration tasks.
4	Pilot outcomes are delivered to WP6 for synthesis

4.1. Pilot scenario description

The main objective of this pilot is demonstrating how joint multimodal management can enable improved flexibility and resilience when facing network disruptions. The pilot will be implemented in a digital replica of the northern metropolitan area of the city of Amsterdam (NL).

A key corridor connecting the northern part of the metropolitan region to the city centre (road s116) crosses the IJ river through an underwater tunnel (IJ-tunnel). In disruption conditions, the tunnel may be partly (i.e., single direction) or wholly closed. Such closures might be planned (e.g., during maintenance) or unscheduled (e.g., due to incidents, vehicle breakdowns…). In case of disruption, the traffic control centre of the City of Amsterdam activates a network management scenario, which comprises of physical barriers closing access to the tunnel, a set of variable message panels informing vehicles about the closure and indicating predetermined route alternatives to the city centre, and ad-hoc tuning of specific Traffic Lights along said alternatives. This pilot will focus on determining under which conditions and assumptions a multi-modal management approach, involving multiple stakeholders (e.g. involving P&R operators, viable alternative transit connections, car-pooling services) can lead to improved resilience to such disruptions.

In this pilot, **AMS** will focus on pilot coordination and ensure that appropriate data collection is set up with the City of Amsterdam, facilitating the development and fine-tuning of the different virtual scenarios. **TUD** will focus on the simulation and impact assessment of different management strategies, both unimodal (e.g. focused on traffic management) and multi-modal, through microscopic simulation approaches (Aimsun, possibly SUMO) and abstract (behavioural) mathematical models. **UGE** will simulate different management strategies with emphasis on regional-scale trip dynamics, including assessing the role of on-demand mobility services, through an agent-based, multi and inter-modal simulation approach (MnMs). **AIM** will support the development, calibration and instantiation of microscopic simulation models. **HERE** will provide additional data for the urban and metropolitan region of Amsterdam, to support model construction and calibration.

Aims and objectives

Through the Amsterdam virtual pilot, we aim to investigate the following aspects:

1) To what extent disruptions (as e.g. generated through the stress tests) affect network performance, considering secondary effects across multiple modes;

2) To what extent traffic management strategies that have been revisited with specific emphasis on enhancing seamless operations (e.g. considering other modes) contribute to improving the resilience of the transport network to disruptions;

3) To what extent different multi-modal coordination approaches can lead to improved resilience in critical disruptions;

4) To what extent automated, AI-assisted multi-modal orchestration can identify and recommend viable management strategies that ensure adherence and collaboration across different mobility stakeholders.

Pilot site description

The city of Amsterdam bolsters a very active business environment, resulting in tens of thousands of job openings each month, and an estimated working population of 520,000 in 2022, a share of 63% of the total resident population. The majority of these workers live outside of the main corpus of the city, rather in the wider metropolitan area: this yields considerable commuting flows (Figures 4.2 & 4.3), which in turn cause considerable road traffic delays as well as overcrowding in public transportation during peak hours.

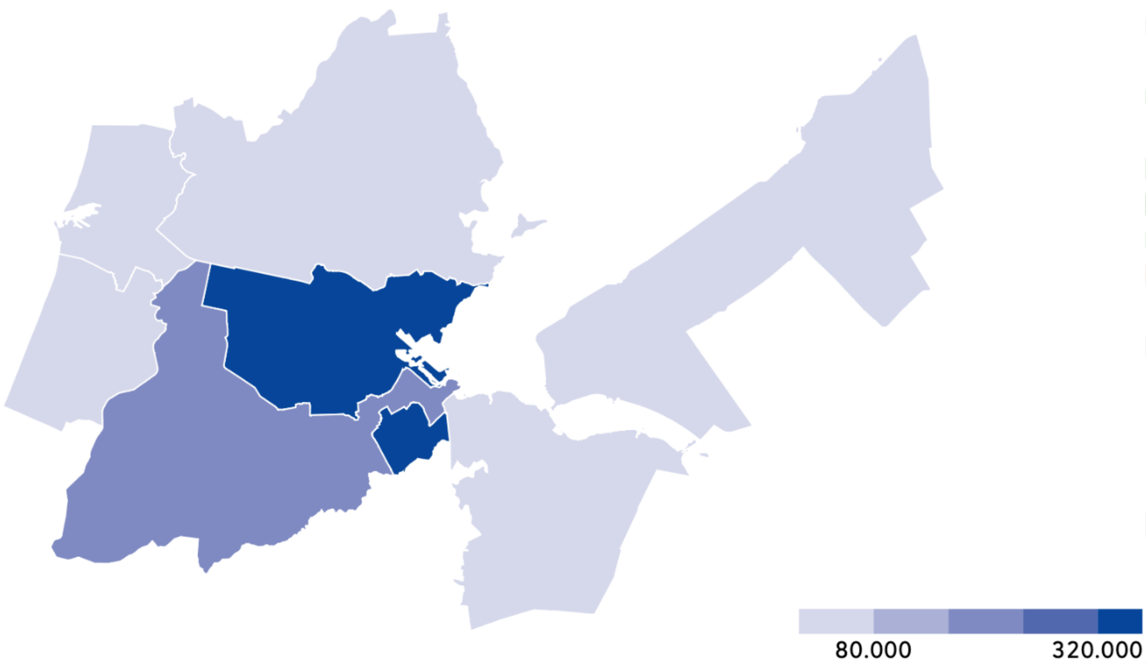

Figure 4.2: Demand pattern in the Amsterdam Metropolitan Region (attraction per municipality, CBS, 2022)

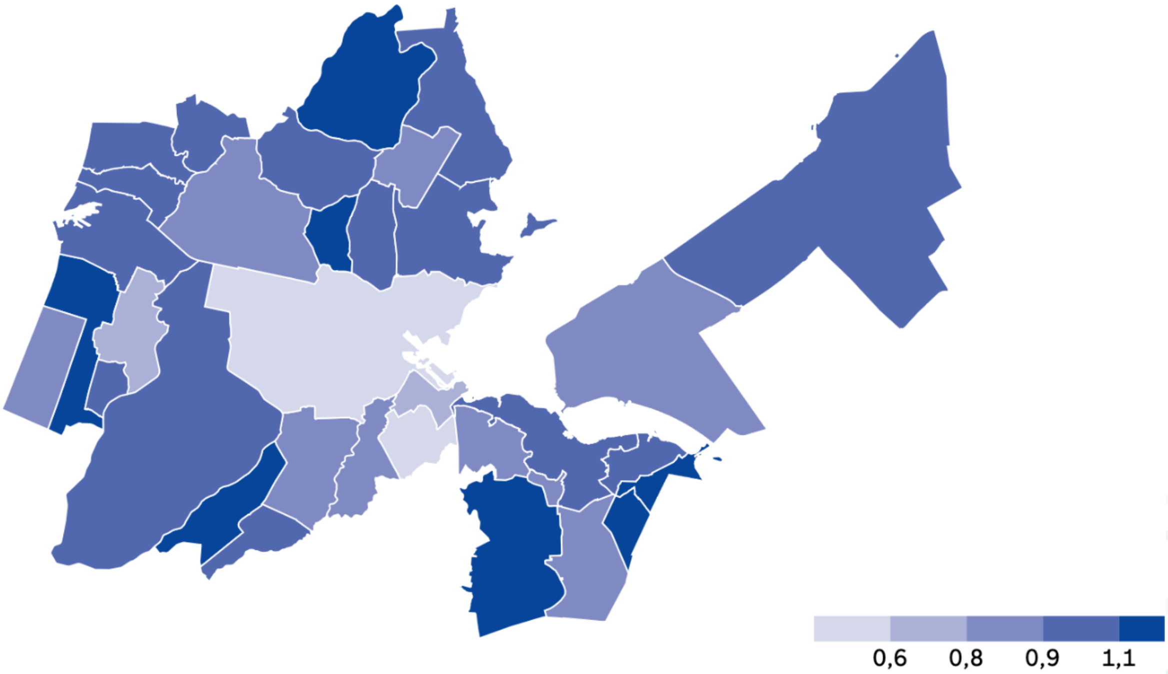

Figure 4.3: Average number of cars owned per household in the Amsterdam Metropolitan Region (CBS, 2022)

Focusing on the north side of Amsterdam, the municipalities of Zaanstreek-Waterland and IJmond are jointly responsible for a total of 140,000 commuter trips per day. For these commuter flows, access to the city centre requires crossing the IJ river, which can be achieved in three main road connections, two of which are on located on the motorway ring road, whereas the third and closest entry point to the city centre proper can be achieved through the s116 regional road, crossing the river via the eponymous tunnel. In typical conditions these traffic flows lead to recurrent congestion patterns, which are managed actively through intelligent access management, ramp metering, preferential P&R routing, etc.

In this pilot, our focus is investigating the situation when the IJ-tunnel is disrupted, either due to scheduled maintenance works or due to incidental conditions. Under such scenarios, rerouting must occur for traffic originating north of the city of Amsterdam and reaching the city centre, redistributing over the motorway ring road and alternative corridors, as sketched in Figure 4.2. In such scenarios, the severity of congestion can increase substantially, leading to undesirable externalities.

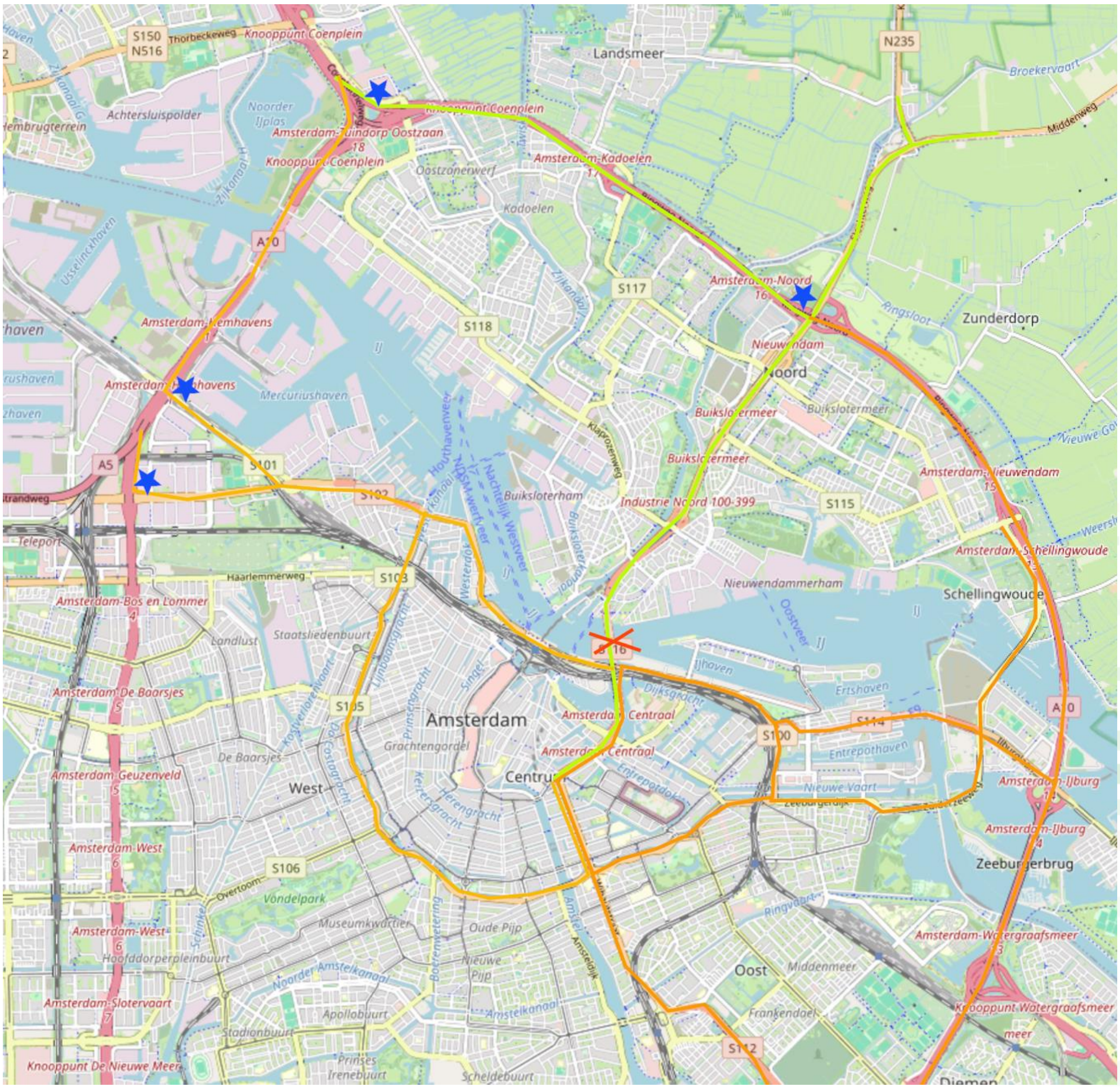

Figure 4.4: Disruption area (red X), disrupted route (green), key alternatives (orange), main variable message panel locations (blue star symbols).

In the current situation, the city adopts a specific Traffic Management strategy to address the tunnel closure, redirecting traffic through variable message signs so that it remains on the motorway ring road, sharing information related to the closure via connected services (e.g., Google Maps, Waze), and adapting the traffic light plans at specific intersections.

Pilot scenario description

In this virtual pilot, our ambition is to evaluate whether the current traffic management strategy could be enhanced through multi-modal cooperative mechanisms. One such example is shown in Figure 4.5, where an alternative to the disrupted tunnel is shown. Commuter flows can be (partly) redirected to leave their vehicle at the Noord Park & Ride location, and rather complete their commuting trip via the newly developed M52 metro line, running parallel to the disrupted tunnel on dedicated infrastructure.

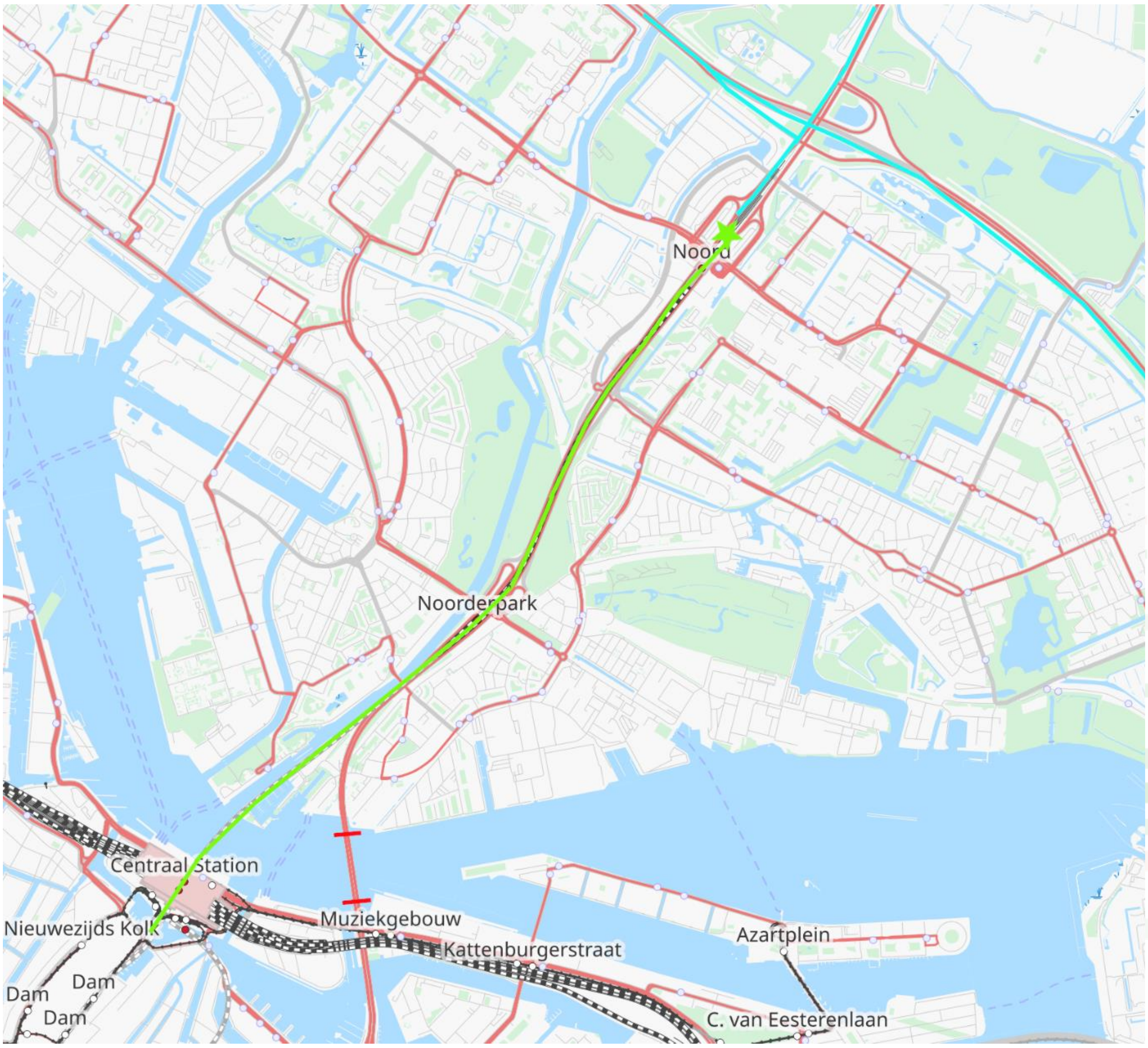

Figure 4.5: Potential multi-modal management approach to be investigated. Park & Ride location (green star symbol), alternative transit line (metro M52, green), rerouted road traffic (cyan).

Following a data collection and homogenisation period, the current traffic management scenario will be simulated at different aggregation scales, to ensure that i) all relevant dynamics at each scale are appropriately captured and ii) that the current scenario is successfully replicated. After this initial calibration phase, different disruption scenarios will be developed, specifically aiming to investigate:

- What modal shift can be achieved by different Traffic Management strategies
- The role of multi-stakeholder collaboration in enabling effective and resilient solutions across the multi-modal transport chain
- The effectiveness of the ACUMEN Digital Twin multimodal decision support tool in identifying viable multimodal management strategies

The virtual pilot will be organised in successive phases:

- Phase 0: calibration and auto-calibration of the different developed models
- Phase 1: evaluation of different single and multi-modal strategies developed identified in the state of the art and/or improved for the sake of promoting seamlessness

- Phase 2: evaluation of strategies generated by the ACUMEN orchestration mechanism, investigation of resilience to different stress test scenarios.

4.2. Summary and Analysis of Data Collected to Date

For road traffic simulation, both traffic flows and signal control strategies need to be calibrated. Considering specifically traffic flow (volume) calibration, the two most adopted approaches are: 1) estimating and adopting an Origin/Destination demand matrix and 2) employing measured intersection volumes and turning ratios. Regarding public transportation network, the timetable that determines the tram/bus frequency and passenger flows need to be collected. Passenger flows are normally calibrated through passenger OD demand, if available.

Currently, three types of related data are collected for this pilot:

1) **Speed data**. This dataset is provided by one of ACUMEN partners, HERE GLOBAL B.V. (HERE). This dataset belongs to the family of “data products”, meaning products or features that utilize data to facilitate a goal. HERE speed data is a data product that provides records of traffic speed observations on roads. Based on GPS probe data, it delivers historical traffic speeds for analytical applications. The data is aggregated and does not contain any personal information. It is fully GDPR compliant. HERE cleans and normalizes its probe data, to assure the highest quality, using advanced algorithms that are specifically tuned for historical data, and more computationally intense than would be practical in real-time traffic feeds. However, natural sample variance is preserved.

2) **Probe trajectory data**. One of the probe data sets used in ACUMEN refers to HERE Probe Data. This dataset includes raw probe vehicle data available as historical data or in near-real time. This dataset will be provided by one of ACUMEN partners, HERE. This dataset finds its sources in connected and commercial vehicles, telematics, and navigation systems, along with smartphones and other mobility services. Besides anonymization of the data, this dataset is not further processed or cleaned.

3) **Detector data**. This dataset is provided by the City of Amsterdam. This dataset features measurements from detectors deployed at signalized intersections, based on which the traffic signal control is applied.

More information on the datasets is given in the following table:

Dataset	Origin	Size	Format	Note
Speed data	HERE	167GB	csv files	2022-01 to 2024-04; have been pre-processed into monthly data; 5 min average speed
Trajectory data	HERE	7.35GB	csv files	496 vehicles, in 2024-03
Detector data	City of Amsterdam	2.72GB	csv files	368 intersections, 15 min volume

4.3. Progress of Model Development

In this section, the progress of model development comprises the simulation networks built based on SUMO and multi-modal traffic management strategies.

Simulation network 1: Northern and centre of Amsterdam

To achieve the objectives of the Amsterdam pilot, a microscopic simulation model based on SUMO is built, including the northern area and the city centre of the Amsterdam, as illustrated in Figure 4.6. As our traffic management strategies did not consider non-motorized participants, bicycles paths and pedestrian paths are not included. Besides, the residential streets that carry little or no commuter traffic are also excluded from consideration, so that the number of nodes and links of the simulated network can be effectively reduced while the effectiveness of the multi-modal traffic management strategies are not compromised as much as possible.

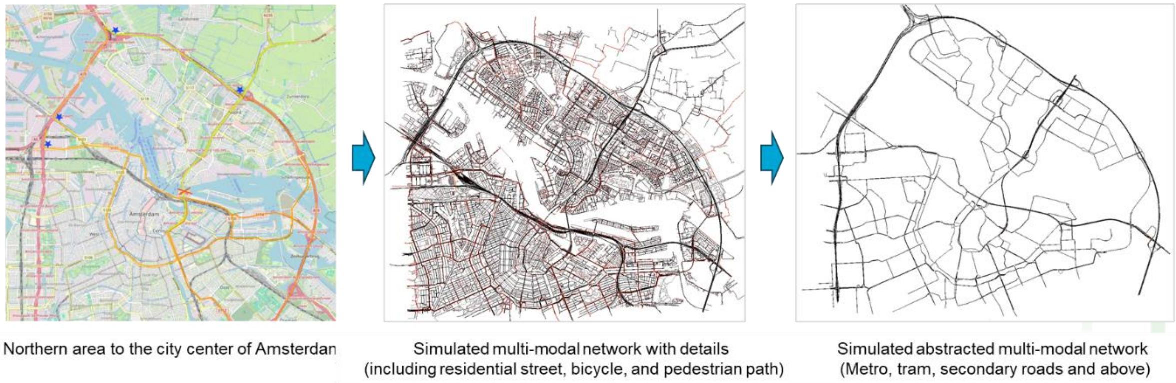

Figure 4.6: Abstracted simulation model by SUMO

The original network imported from OpenStreetMap has a number of problems, such as the absence of some essential commuter links, disorganized intersections, and unclear connections between links. Thus, the network needs further cleaned, including operations such as removing isolated links, joining nearby intersections, correcting connections/lanes, and adding necessary links. Finally, an abstracted multi-modal network is built, which consists of 111 traffic lights, 1670 nodes, and 2954 edges.

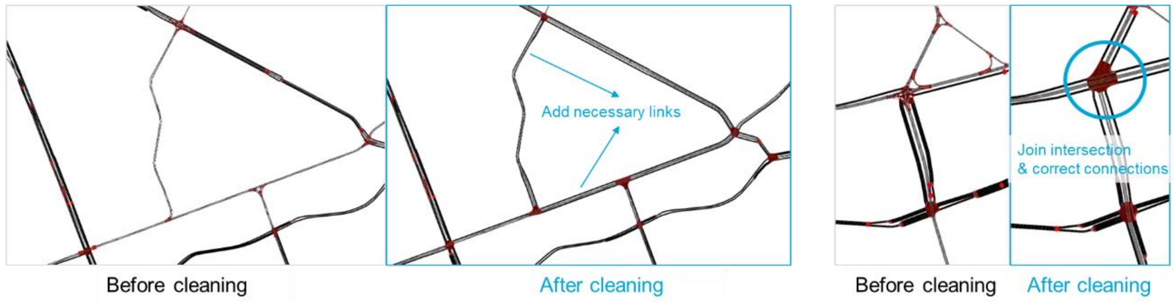

Figure 4.7: Examples of cleaning the imported network

In addition to road traffic network, the public transportation network is also imported, including metro stations, bus/tram stops, dedicated lanes, and Park&Ride area.

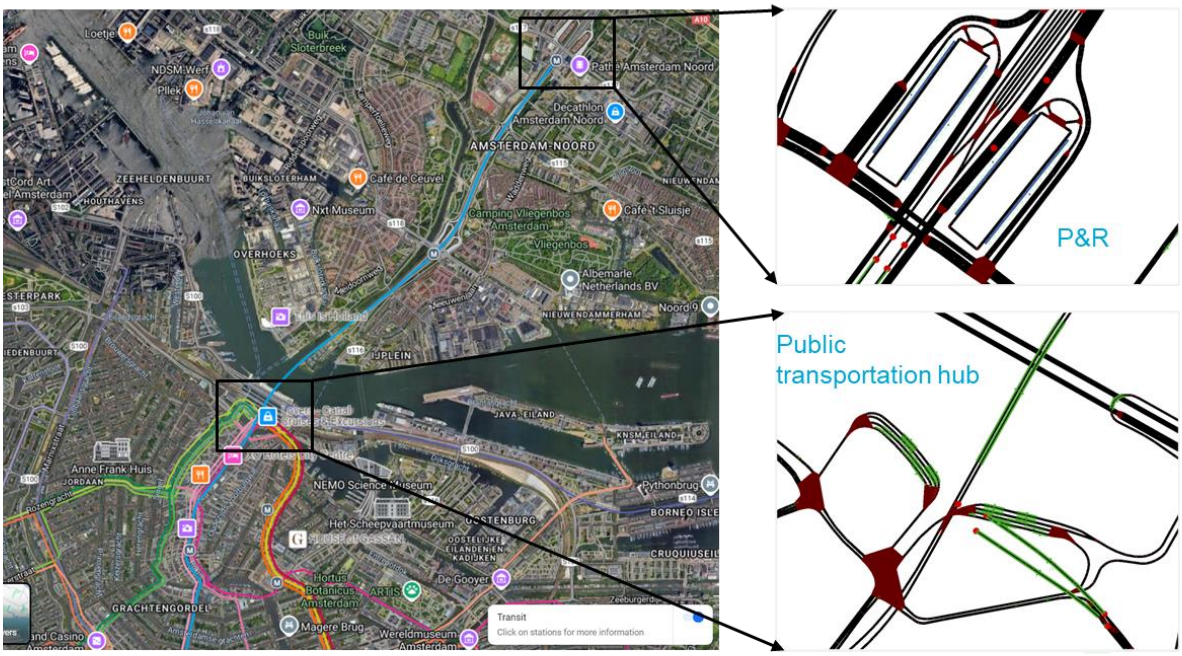

Figure 4.8: Imported public transportation network

Simulation network 2: A Corridor that the detour route will pass through

If the tunnel connecting the northern area to the city center is closed due to disruptions , some commuters may choose a detour route to the city centre, leading to increased traffic volume along the detour route. Hence a multi-modal traffic signal control strategy for such a case is necessary. To effectively test the multi-modal traffic signal control strategy, a smaller simulation network with 3 signalized intersections on the detour route is built, which includes 7 tram lines and 8 buses lines with conflicting request at signalized intersections.

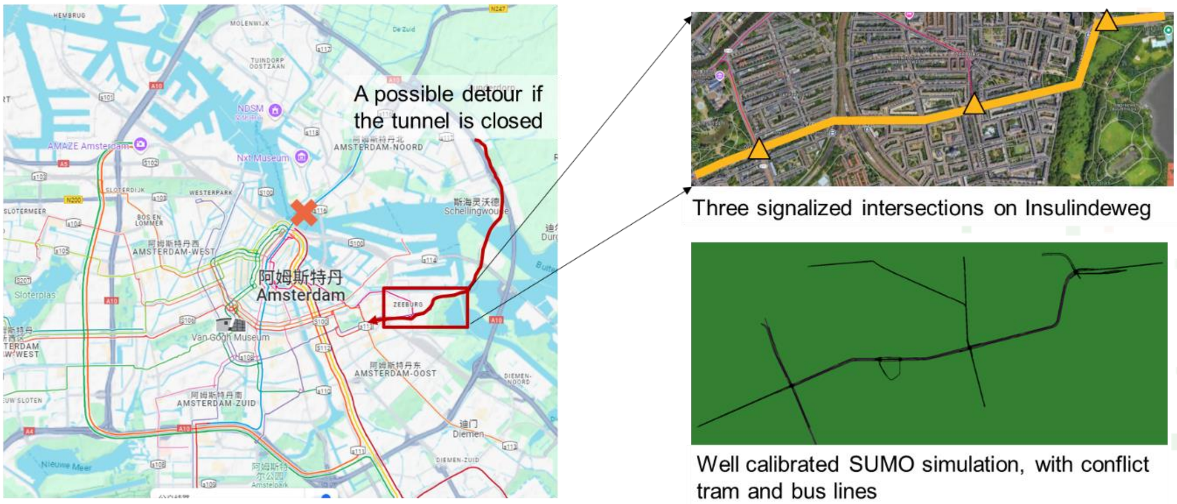

Figure 4.9: Simulation model 2 – critical corridor

Multi-modal traffic signal control strategy

In the case when the tunnel connecting the northern area and the city centre of Amsterdam is closed due to unexpected disruptions, traffic volumes at alternative detour routes may suddenly increase, leading to abnormal congestion at intersections along these alternative detour routes. Thereby, in order to reduce congestion as much as possible and to ensure that public transit vehicles can still enjoy signal priority despite the increase in private vehicle traffic, a transit signal priority method that extends the max-pressure control is developed, namely Transit-MP, which determines the green phase based on person-based measurement thus achieving signal priority in a “soft” way.

To test this multi-modal traffic signal control strategy, initial tests based on Simulation Network 2 are being conducted, which aims to: 1) compare Transit-MP with traditional or empirical transit signal priority method; 2) evaluate the performance of Transit-MP in the scenario with suddenly increased private vehicle traffic. After demonstrating the performance of Transit-MP in Simulation Network 2, at the final stage, Transit-MP is planned to deploy in the larger network, Simulation network 1, accompanied by other multi-modal traffic management strategies, such as vehicle route guidance, perimeter control, to show how much these multi-modal traffic management strategies can improve the performance of the whole multi-modal network.

Next steps

Regarding the simulation networks, the traffic demands of the Simulation Network 1 needs to be calibrated, including origin/destination demands of private vehicles and travel demands of passengers.

Regarding the multi-modal traffic signal control strategy, more experiments on the simulation corridor is required, with further consideration of transit timetable and integration of transit vehicle speed guidance. Besides, further experiments on Simulation Network 1 are also expected.

4.4. Other activities and Achievement

N/A

4.5. Alignment with Timeline

At the date of writing, the virtual pilot development process is correctly aligned with the expected timeline.

Key dependencies (work package links that depend on the development of the Amsterdam pilot) are primarily associated with WP5 (integration with the Digital Twin) and WP6 (Pilot analysis and management). Early integration attempts employing the smaller simulation network (Figure 4.9) are currently underway, so to facilitate full integration for the Amsterdam virtual scenario later in 2025.

5. Luxembourg pilot (Task 6.5)

Contact list & Partners involved

Contact list

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Partners involved

Partner	The role in this pilot
UNILU	Pilot leader / develop a demand model and routing and scheduling models for a real-world pilot. Run simulation-based experiments for different scenario.
SLA	The shuttle service operator
LIST	Instantiation of DT for this pilot
LUXM	The analysis of the data, the identification of KPIs and assessment of the impacts.

Timeline

A timeline of the Luxembourg pilot is summarised in the figure below.

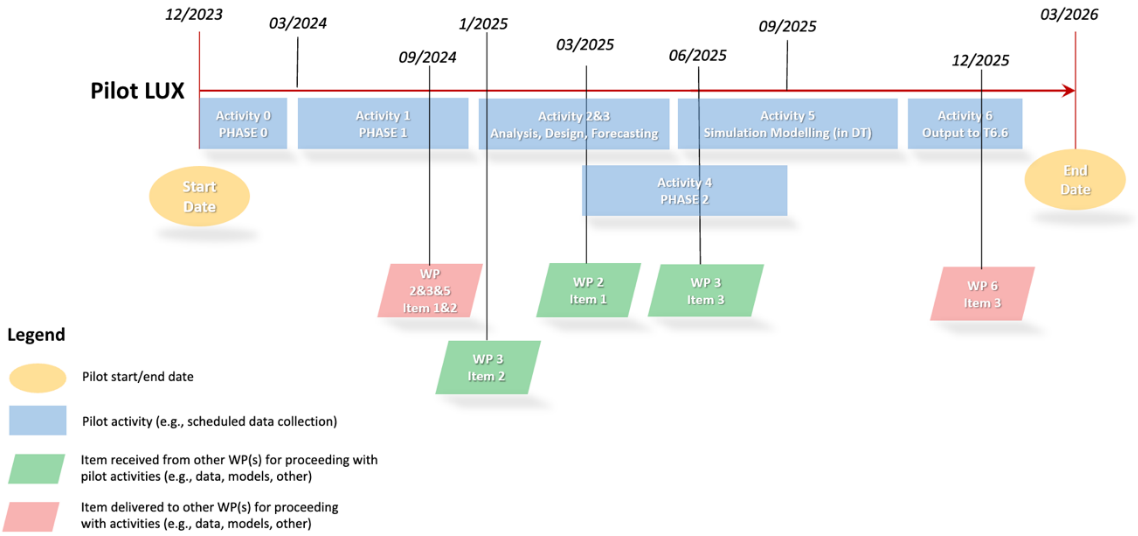

Figure 5.1: Timeline for Luxembourg Pilot

Table 5-1 Activities (in red the changes wrt the original plan)

Activity	Description	Planned Execution period	Status
1	Start data collection from shuttle. Start online data collection: live transport information, weather etc. Start the shuttle service using manually driven (electric) shuttle buses. ~~Data collection for digital twin [NMK]~~ Drone data collection is delayed due to NMK replacement. This is not affecting other data collection or activities due for this period in the pilot.	01/03/2024 - 31/12/2024	On time (except for the drone data collection) NMK left the consortium, and their tasks are being reassigned to other partners following an amendment submitted to the European Commission.
2	Analysis of collected data. Plan potential extension & improvement of service (to additional stops): design Phase 2	01/1/2025 - 31/05/2025	Started in advance
3	Modelling: demand forecasting [Task 3.2]	01/1/2025 - 31/05/2025	No delay expected
4	Phase 2	01/03/2025 - 30/09/2025	No delay expected
5	Calibrate simulation model(s)	01/10/2025 – 30/01/2026	No delay expected

Table 5-2 Input items

Item	Description	Planned Execution period	Status
1	WP2: might need to know if there is a data template we should comply with.	01/2025	No delay expected
2	WP3: demand modelling/forecasting	03/2025	No delay expected
3	WP3: Task 3.3 calibration of simulation models deployed in WP5	06/2025	No delay expected

Table 5-3 Output items

Item	Description	Planned Execution period	Status
1	Service data, Demand data, Vehicle data. -> WP3 for developing models [Task 3.2 & 3.3] -> WP2 to be integrated into the data fusion framework [Task 2.2]	09/2024	Data has not been required from WP3 and WP2 in September 2024. We will provide the data upon their requests
~~2~~	~~NMK data -> WP5 -~~ Drone data collection (expected for 2025) is expected to be delayed due to NMK replacement. (see Table 5.1). Collection is now expected to be done in mid-2025.	~~09/2024~~ (expected Jun 2025)	NMK left the consortium, and their tasks are being reassigned to other partners following an amendment submitted to the European Commission.
3	Outputs sent to WP6 for synthesis	12/2025	No delay

5.1. Pilot scenario description

The main objective of this pilot is to demonstrate to what extent seamless and integrated mobility can improve mass transit users' experience. This pilot will be implemented in two sites: (i) Contern, an industrial area where an existing last-mile service connects employers with the nearby train station. (ii) Esch-sur-Alzette, a peri-urban commune south of Luxembourg City that is home to both residential and commercial zones with a mix of employers, services, and activity locations (restaurants, shops). In this pilot, SLA will deploy two types of shuttles.

In Contern, a conventional fixed route and fixed schedule service will be replaced by an optimised on-demand service. This will allow increased responsiveness and flexibility, and seamless integration with mass transit. In Esch-sur-Alzette an autonomous shuttle runs on an 800m route along pedestrian streets with cross traffic. The shuttle currently operates from 11 am to 6 pm with fixed stops and frequency. Companies, users and inhabitants in the area are interested in a more flexible service that will require additional stops or stop skipping.

User acceptance and wider citizens and societal considerations, as well as willingness for uptake will be assessed by LUXM making use of its Mobility DST. Service providers and local authorities will be engaged to understand their views and encourage local collaboration and knowledge-sharing.

The Contern pilot has already begun in Phase 0 and progress to date is presented below.

The Esch-sur-Alzette pilot will begin in Phase 2 and hence progress is not reported in this deliverable.

Aims and objectives

With the objective to demonstrate the impact of improving the seamless door-to-door travel by mass transit service, we will conduct two real-world pilots and one simulation-based pilot.

During the real-world pilot, we aim to investigate:

1) To what extent, the shuttle will experience the delays and disruptions during the operation for both scheduled and on-demand services.

2) To what extent, introducing on-demand feature in the last/first-mile shuttle increase the user experience and shuttle patronage.

During the simulation-based pilot, we aim to identify the following objectives:

3) How can the service be augmented to best serve increased demand in the future.

4) To what extent the shuttle schedule can adapt to and mitigate disruptions in mass transit (e.g., delays in arrival).

Pilot site overview: Contern

The existing service is operated by SLA: a 2.3km route stopping only at Campus Contern and the Sandweiler – Contern station. There is one train line passing a Sandweiler – Contern station which connect the Luxembourg city, CBD of Luxembourg and Trier in Germany which is one of the common habitants for Cross border commuter. In 2022, 926 people are getting on/off at this station per day in average[2]. There are also 3 bus lines close to the Sandweiler – Contern station where 852 people are getting on/off at the stop in average per day in 2022. The 2 bus lines out of 3 are connected to the campus Contern.

[2] TRAIN - Plan - TRANSPORT Portal - Luxembourg (public.lu)

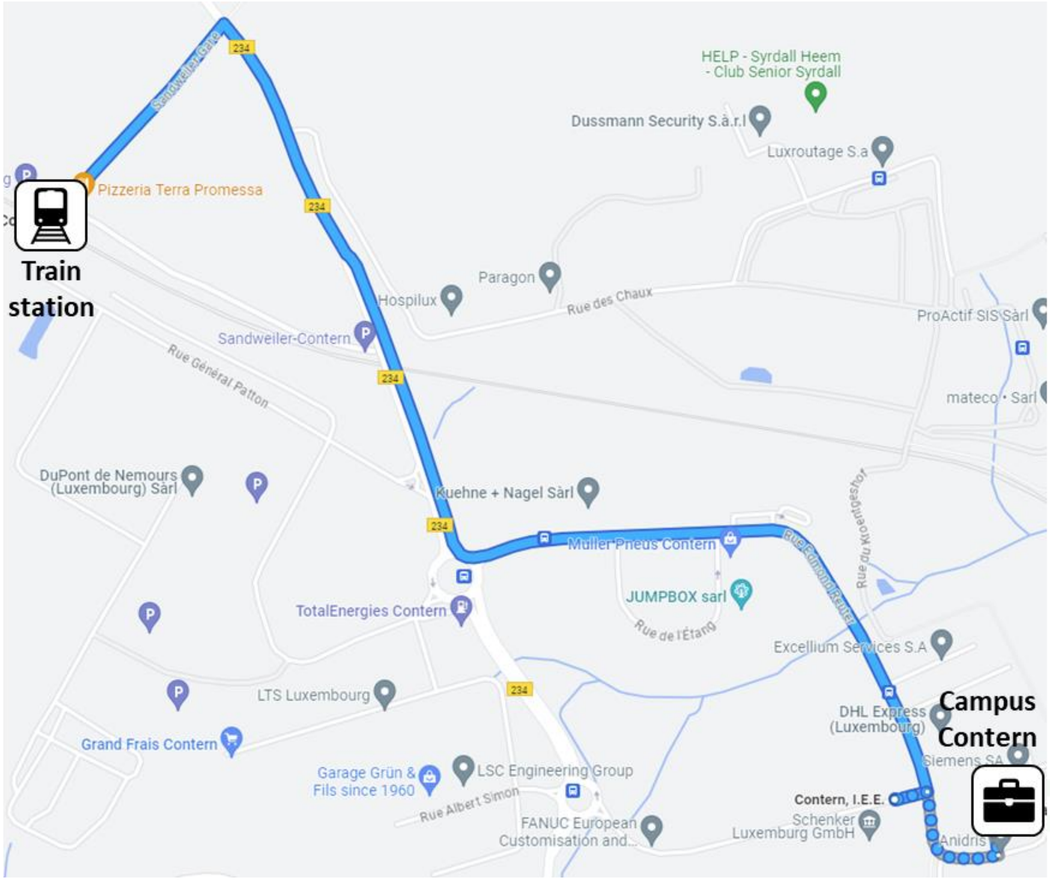

Figure 5.2: Luxembourg pilot study area with shuttle route

Currently, the shuttle runs from 7 to 9 a.m. and from 4 to 7 p.m. It takes approximately 7 min to travel between two stops by bus, 4 min by car, and 32 min by walk. Assuming the shuttle operates similarly to a private car (as there is no stop between), it will also take 4-5min to travel by a shuttle. However, as a shuttle schedule is not synchronised with bus and train schedule, users may need to wait at the stop to get in a shuttle. During the real-world pilot, the service feature of the shuttle will be modified as specified in the table below.

Table 5-4 Summary of how the service feature of the shuttle will be modified during the real-world pilot

Service feature	Phase 0	Phase 1	Phase 2
Schedule	Fixed	Departure time changes based on users' request	Additional flexibility of the service will be investigated based on the app and building on results of Phase 1
Route	Fixed	Fixed	
Stops	2 stops Contern station Campus Contern	2 stops Contern station Campus Contern	
Integration to mass transit	No consideration	Not explicitly considered	
Is it On-demand?	No	Yes	Yes
Communication with users	No communication	Through the app	Through the app

Description of the app for Contern

SLA is currently developing the mobile app. The application will be the main interface between the vehicle driver and the shuttle users.

This application will have two main functions.

- On the user side, the user can book a reservation for a vehicle to be sure that the vehicle will be present at the chosen place and time, and that the vehicle will have enough place to take the number of passengers booked to the destination.
- On the driver side, the application will inform the driver of the pick-up locations and times, with the number of people who must boarding in the vehicle.

The application will communicate the final destination and indicate if any passengers need to be picked up at an intermediate point.

- For the providing operator service, the application will do the possibility to evaluate the quality of the provided service by comparing the reservations made to the really daily schedule day with accurate and certified data.

Firstly, this will also make it possible to better understand the users' habit to optimize the service (in particularly the pick-up and end of service times).

Secondly, this can help us for significant savings, particularly in the energy costs, by reducing the empty trips and providing a better daily work experience to the driver who avoids unnecessary driving when there is no reservation.

The figure below shows screenshots of the booking app where users can specify their pickup location, pickup time, and drop-off location.

After creating an account, the user can book a trip. To do this, he must indicate:

- Where (s)he wants to leave from and which terminus he wants to reach.
- The number of passengers, the date and time of the pick-up.
- The type of transport (s)he used to joint to the pick-up point.

After, the application confirms if the vehicle is available at the requested location/time, for the number of passengers indicated and estimates the arrival time at the final destination.

The user confirms the reservation and is notified with a confirmation. Then, the driver receives the reservation and go to the location chosen by the user at the right time and day.

When the driver is at the pick-up location, (s)he confirms it on the application. The customer is notified that the vehicle is waiting for them.

The user will go to the pick-up point and go inside the vehicle. The driver confirms on the application the number of passengers picked and validates and drive to the next pick-up point or to the final destination, if there is no other reservation.

If a reservation is requested by another user, and within the same time window and along the initial path of the first reservation, it is accepted by the apps and the driver is informed to stop at an additional area. The only condition is to have enough available seats in the vehicle.

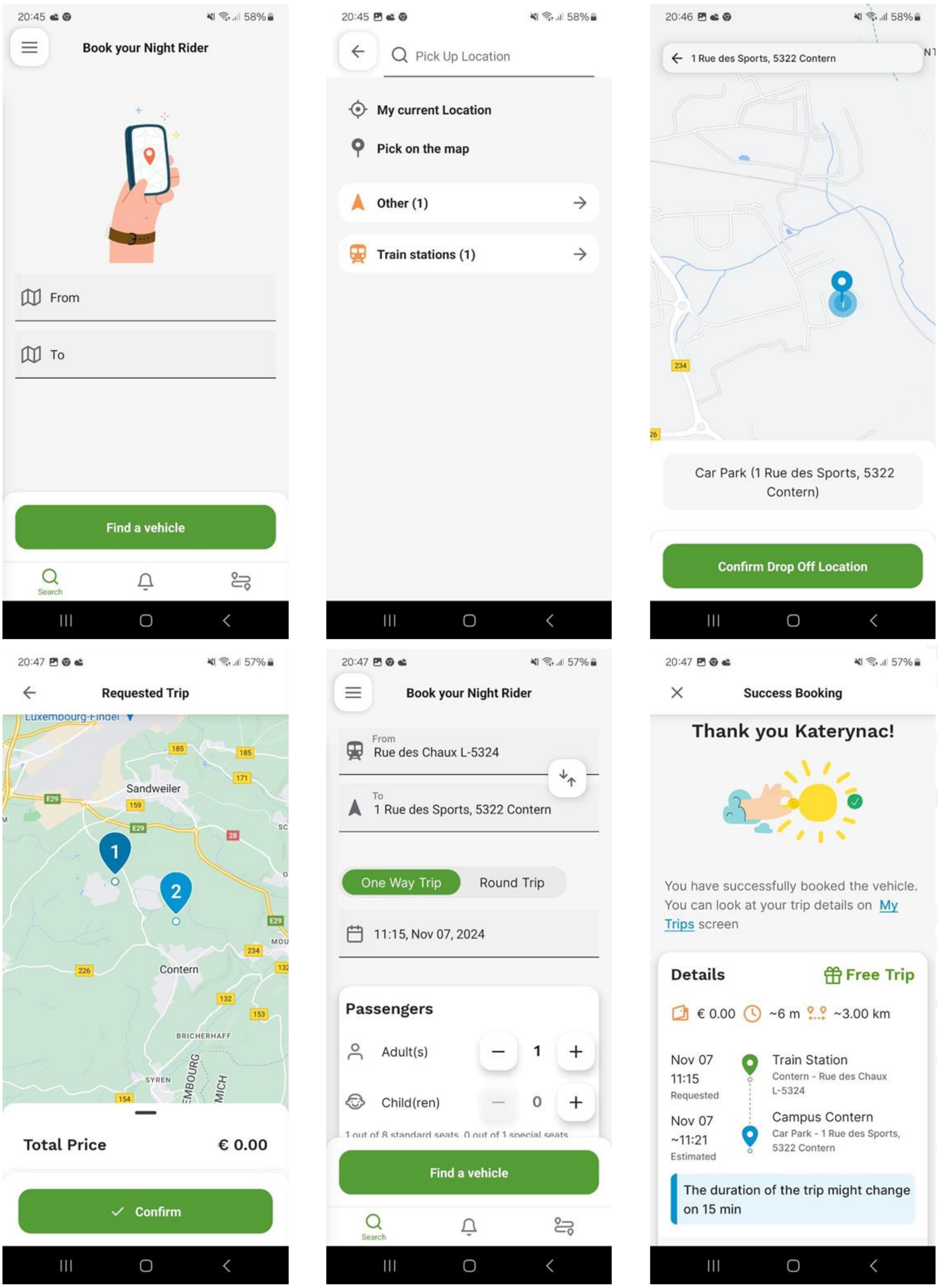

Figure 5.3 the series of screenshots of the booking app from the start (the left top) to the successful booking (the right bottom)

Scenario description: Contern

The pilot consists of three phases where the first two phases will only be the real-world experiment, and the last phase consist of both real-world and simulation-based experiments.

During phase 0 and phase 1, demand and service-related information will be collected, which will be used as inputs for the model which optimises the shuttle services for the second real-world pilot in phase 2. Also, those data will be inputs for simulation-based experiment to be conducted in phase 2 as well as the data collected from the second real-world pilot in phase 2.

Phase 0: Baseline data collection

Run the shuttle service without any intervention and collect data including

- Number of passengers getting on/off at each stop
- Number of total trips that shuttle made

Launch questionnaire survey to employees of campus Contern to ask their usual commuting mode and their perception towards the current shuttle service (e.g., if they know the service, why they do not use the service).

Current Status: Phase 0 has been initiated, and data collection is complete. Preliminary analysis of the collected data has been conducted, and the results are presented in Section 5.2. This data is used as benchmark against the on-demand service in Contern to evaluate the performance improvement of the system for both operator and customers.

Phase 1: Running the service as on-demand shuttle

Run shuttle as on-demand service. SLA will develop an app through which users can book a shuttle in advance. With this pilot, we expect to collect data including;

- Passenger's expected pick-up or drop-off time (depending on the booking system)
- Which train/buses they are taking to or coming with (through the app, otherwise, infer from their booking information)

We plan to launch follow up interview/focus group discussion or questionnaire survey to understand how users' perception and experience changed.

Current Status: Phase 1 is scheduled to commence in early 2025. A key milestone in preparation for this phase is the development of the on-demand service app. This app is now ready to be tested. The app is expected to be presented at the November 2024 workshop and to be fully operational by the end of 2024.

Phase2: Running the service with optimised strategy, plus simulation-based pilot

Based on the data collected and analysed in Phase 0 and phase 1, a new service strategy will be developed and tested in the Contern pilot. The app will provide the interface between users and service provider enabling the shuttle service to be responsive to demand.

The autonomous shuttle pilot will be deployed in Esch-sur-Alzette. The experimental details are under development, being informed by the ongoing autonomous service, and the characteristics and constraints of the operational area. Initially, rescheduling of the service will be tested by stop skipping.

Finally, simulation experiments based on the Contern pilot will test additional research questions including:

- How can the service be augmented to best serve increased demand in the future.
- To what extent, the shuttle schedule can adapt to and mitigate disruptions in mass transit (e.g., delays in arrival).

The development of the simulation model is progressing according to schedule as reported below in Section 5.3.

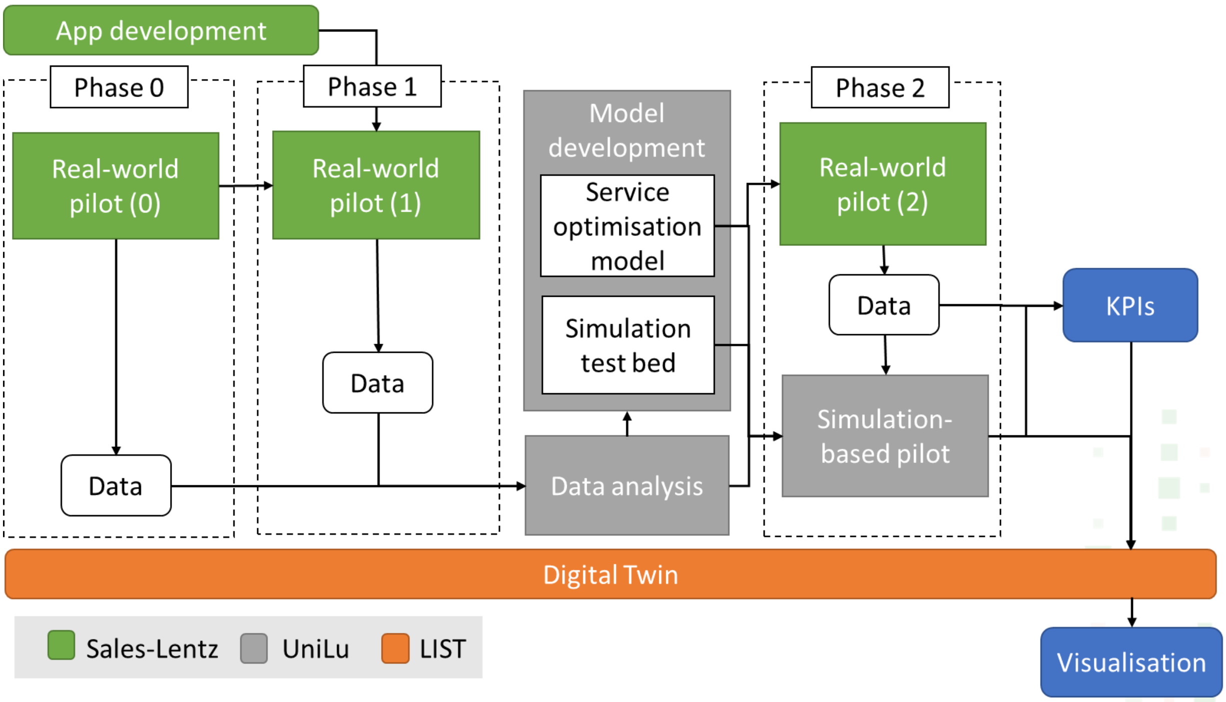

Figure 5.4: Phases of the Contern pilot

5.2. Summary and Analysis of Data Collected to Date

As part of the Luxembourg pilot, two key datasets have been gathered to date:

1) Operational Data from the Fixed-Schedule Minibus currently running at Contern
2) Mobility Survey Results from a questionnaire collected in Campus Contern

In the following sections, we provide an in-depth overview of the data collection methods, the characteristics of each dataset, and preliminary insights drawn from the analysis.

Operational Data from Fixed-Schedule Minibus at Contern

This section presents the preliminary analysis of the operational data from fixed-schedule minibus at Contern run by SLA collected from 4th December 2023 to 8th December 2023. While this report focuses on data from five days, more extensive data collection is ongoing and will be analysed in subsequent phases of the project.

Figure 5.5 illustrates the total travel time for the minibus during morning (AM) and afternoon (PM) operations in the Contern area. Notably, on December 6, 2023 (Wednesday), the minibus did not operate and returned to the SLA depot located at 4 Bascharage Käerjeng. This deviation suggests that unplanned maintenance was required, as the service is intended to run on all weekdays.

The analysis indicates that the total travel time tends to be longer during the afternoon operations compared to the morning runs. Additionally, significant fluctuations in travel time are observed, particularly between Monday/Tuesday and Thursday/Friday. A more comprehensive analysis using the complete dataset is necessary to determine if there are consistent patterns in these travel time variations throughout the week.

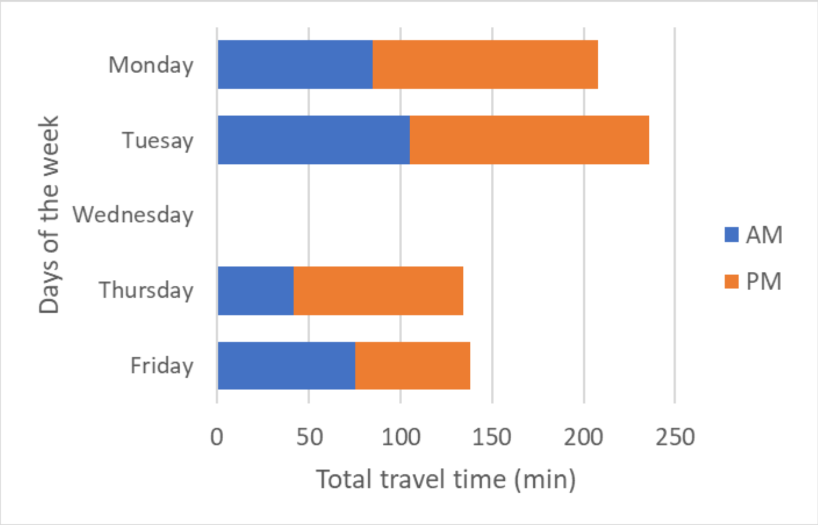

Figure 5.5 The total travel time on minibus from Monday to Friday

After completing the morning (AM) operations, the minibus consistently returns to the depot. However, no charging activity was recorded between the AM and PM operations during the analysed week, suggesting that recharging occurs exclusively overnight.

Figure 5.6 presents the average energy consumption rates for the AM and PM operations. Although day-to-day variations in energy consumption rates are minimal, the data indicates that energy consumption is higher during the AM operations on Monday and Tuesday, while it reverses, with higher PM consumption on Thursday and Friday.

It is known that colder temperatures can lead to increased energy consumption. However, Figure 5.7. does not show any significant correlation between energy consumption and temperature fluctuations for the period analysed. A more in-depth analysis using the complete dataset will be necessary to assess the extent to which environmental conditions impact energy efficiency compared to other potential determinants, such as driving behaviour.

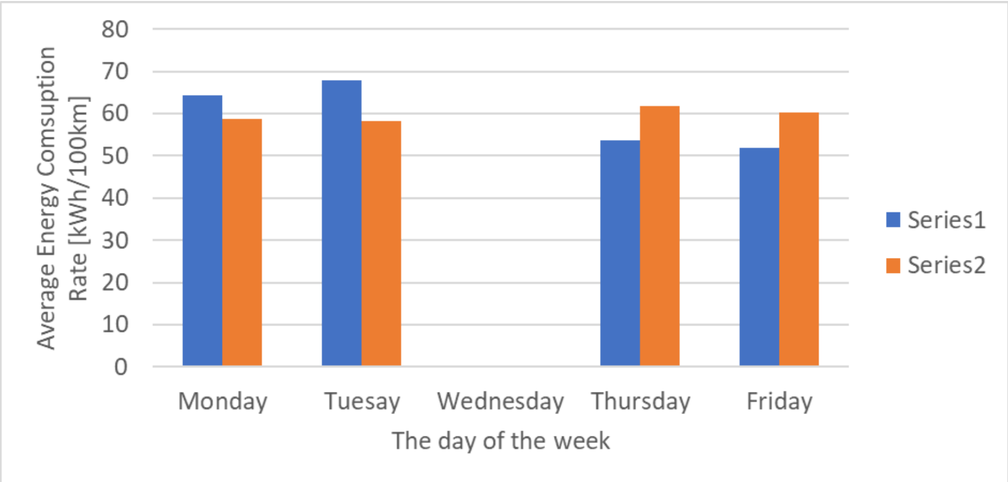

Figure 5.6 The average energy consumption rate for AM and PM operation for each day of the week

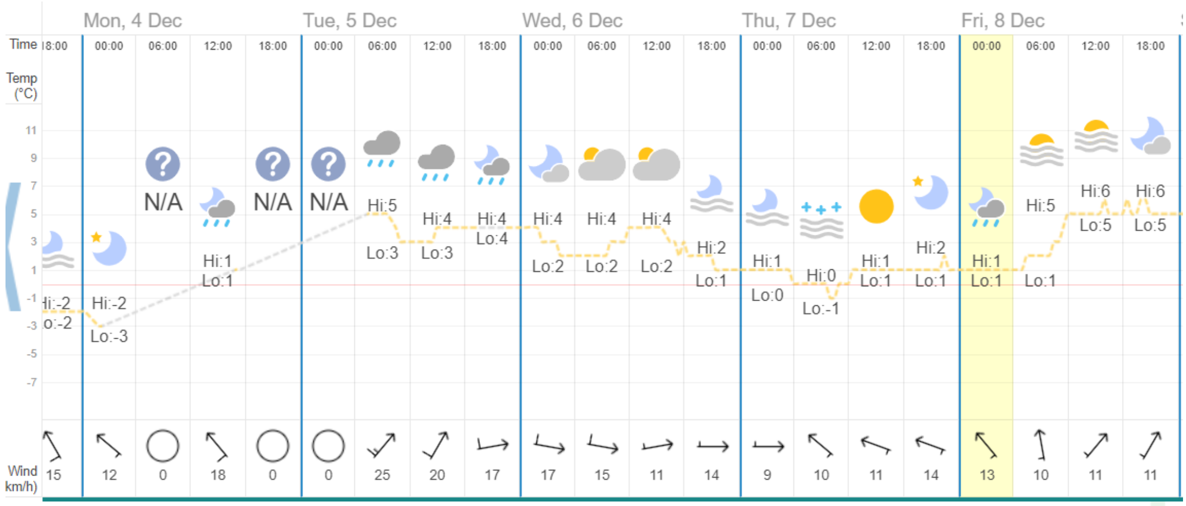

Figure 5.7 The weather data in Luxembourg from 4th to 8th December (Weather in December 2023 in Luxembourg, Luxembourg)

Mobility Survey Results: Contern

Campus Contern recently conducted a mobility survey aimed at its employees, who are the primary users of the scheduled mini shuttle service operated by SLA. The survey comprised six key questions designed to understand transportation preferences and gather feedback on the shuttle service. These questions were:

#	Questions
1	Which mode of transport do you prefer to use when commuting to Campus Contern?
2	Do you use the free electric shuttle that operates between the train station/bus stops and Campus Contern?
3	If you use the free electric shuttle, are you satisfied with the service?
4	If you do not use the shuttle, what is the reason for not using it?
5	Would you be interested in using the shuttle if it became an on-demand service via a booking application?
6	Do you have any additional comments or suggestions?

A total of 67 responses were collected, and the survey results are summarized below.

Figure 5.8 illustrates the findings from Q1. It reveals that approximately 75% of respondents consistently commute by private car, while around 11% rely solely on public transport. The remaining respondents alternate between different modes of transportation, including private car, carpooling, and public transport.

Interestingly, 79.1% (53 out of 67) of respondents reported not using the shuttle service between Contern station and Campus Contern (see Figure 5.9), a percentage even higher than those who regularly commute by car. This suggests that while some individuals may occasionally use public transport, they do not take advantage of the shuttle service but instead use other alternative bus lines.

According to the results of Q3, all shuttle users reported being either "very satisfied" or "satisfied" with the comfort of the shuttle (see Figure 5.10). However, 4 respondents expressed dissatisfaction with the shuttle's timetable, and 2 were unsatisfied with its reliability. While these numbers may seem small, they represent 28% and 14% of all shuttle users, respectively—figures that cannot be overlooked.

The timetable received the fewest "very satisfied" responses, with less than 50% of respondents expressing high satisfaction, signalling significant room for improvement. Question 3 also included a section where respondents could provide written recommendations (see Table 5-5). Of the six comments filled, four were directly related to the timetable, with suggestions to either start the shuttle service earlier or extend it to later times, thereby covering a wider range of schedules. The remaining comments focused on the service's reliability. One respondent shared an experience of missing their intended train, stressing the importance of better coordination between the shuttle and train schedules to enhance the overall service quality.

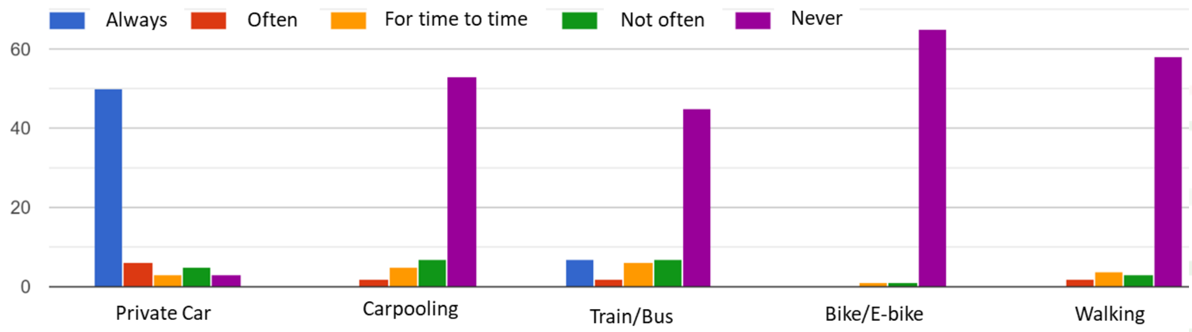

Figure 5.8 The results of Q1 – which mode of transport do you prefer to use when commuting to Campus Contern?

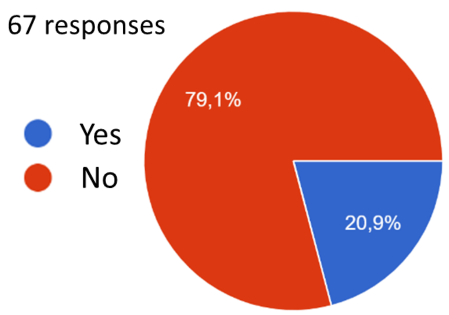

Figure 5.9 The results of Q2 - Do you use the free electric shuttle between the train station/bus stops and Campus Contern?

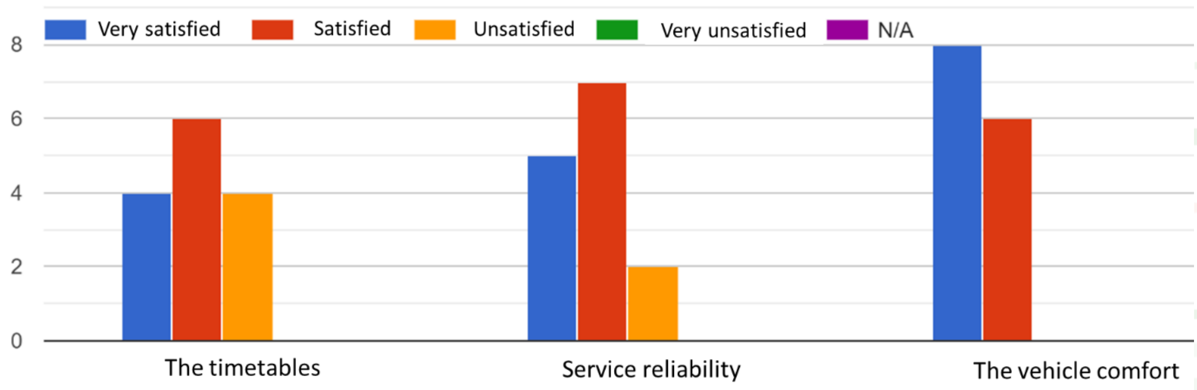

Figure 5.10 The results of Q3 - If you use the free electric shuttle bus, are you satisfied with the shuttle service?

Table 5-5 the comments and suggestions from the respondent regarding the service satisfaction level (part of the results of Q3)

Comments/suggestions	Categories
It might be appropriate to add one or two times in the morning, to come from Contern station. Perhaps until 9:30 instead of 9:10.	Timetable
Advance the first departure from the station to 07:15	Timetable
The Shuttle should go at 10am in the morning and not stop at 9:20	Timetable
As trains from Germany are often late, I miss the last shuttle bus. There are a few people starting their work between 9:00 and 10:00, so it would be great if shuttle schedule in the mornings could be extended to at least 9:30.	Timetable
Sometimes the shuttle does not arrive on time and then I lost my train and 2 or 3 times in the last months the shuttle directly did not appear.	Reliability
It is very important that the schedule is adhered to and that you can rely on it. That has improved significantly. The regular driver in particular is very nice and reliable.	Reliability

According to Figure 5.11, the most common reason for not using the shuttle service is that respondents do not use trains or buses. Although this was only mentioned by one respondent, the issue of poor connections was also noted. In general, people expressed a positive attitude towards the idea of transitioning the shuttle to an on-demand service with bookings available via an app. Given that 79.1% of respondents currently do not use the shuttle, it is reasonable that "no opinion" was the most frequent response.

The last question gave respondents the opportunity to share their general opinions about the shuttle. One comment stated: *“In the evening or afternoon, it would be nice to be able to contact the driver to confirm the exact departure time or to see it in the app—if there is one. Since people leave the office in the evening at different times, this would help us not to miss the shuttle by a minute or a few minutes.”* This feedback highlights the potential for service improvement when an on-demand and booking system is introduced, offering greater flexibility and reducing missed connections.

In addition to the two datasets mentioned above, real-time train and bus departure information has been recorded for Contern station and Esch-sur-Alzette station since January 2024. As the preliminary analysis of this data is still ongoing, it has not been included in this report. However, this work is currently in progress.

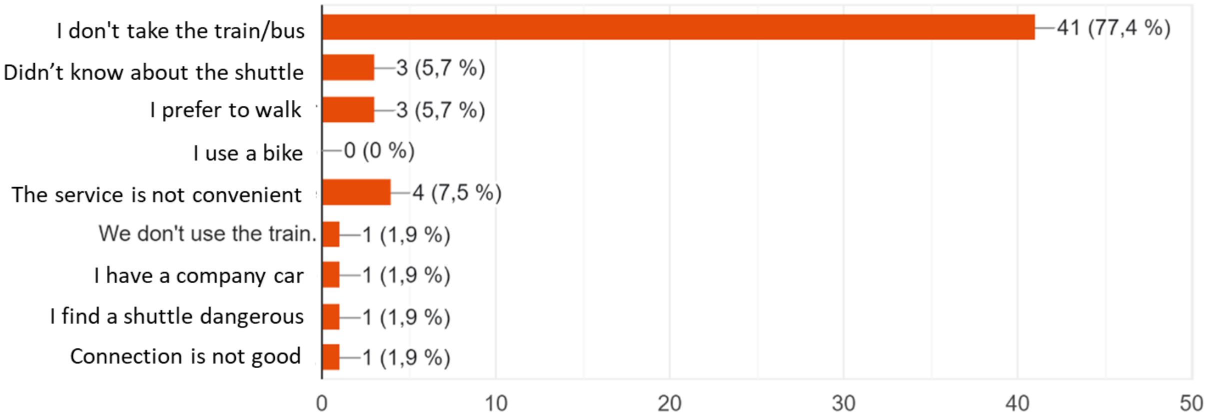

Figure 5.11 the results of Q4 - If you do not use the shuttle, what is the reason for not using it?

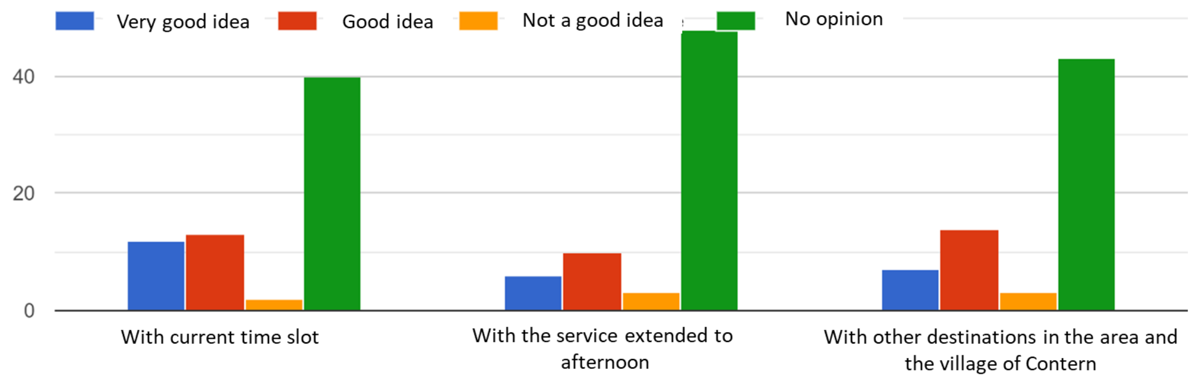

Figure 5.12 the results of Q5 - Would it be a good idea if it became an on-demand service with a booking application?

5.3. Progress of Model Development

This section provides an overview of the current stage of model development, which will be utilized in the forthcoming simulation experiment. This model aims to implement a demand-responsive transport (DRT) solution based on the metaheuristic algorithm within the MATSim environment to evaluate the service's potential attractiveness under semi-realistic conditions.

The metaheuristic algorithm for DRT service has jointly been developed by MobiLab Transport Research group at University of Luxembourg and Luxembourg Institute of Socio-Economic Research as part of FNR CORE M-EVRST project. The detailed structure of the metaheuristic algorithm and the formulation of the problem can be found in Ma et al. (2024) [3]

MATSim (Multi-Agent Transport Simulation)[4] is an open-source framework designed to simulate large-scale transportation systems. It uses an agent-based approach, where each agent represents an individual traveller with specific preferences, schedules, and behaviours. Although MATSim has a built

[3] Ma, Fang, Connors, Viti and Nakao. 2024. A hybrid metaheuristic to optimize electric first-mile feeder services with charging synchronization constraints and customer rejections, *Transport Research Part E*, 185, https://doi.org/10.1016/j.tre.2024.103505
[4] A. Horni, K. Nagel, and K. W. Axhausen,2016. The Multi-Agent Transport Simulation MATSim

in DRT module where it can run DRT service in MATSim environment, its configuration is not suitable when the DRT is assumed to be used for a last and first mile connection to the scheduled transit service.

Pipeline overview

Figure 5.13 shows the overview of the pipeline that integrate DRT solver (written as DRT MILP model in the figure) into MATSim simulation framework. In the following section, the brief description of each step will be presented.

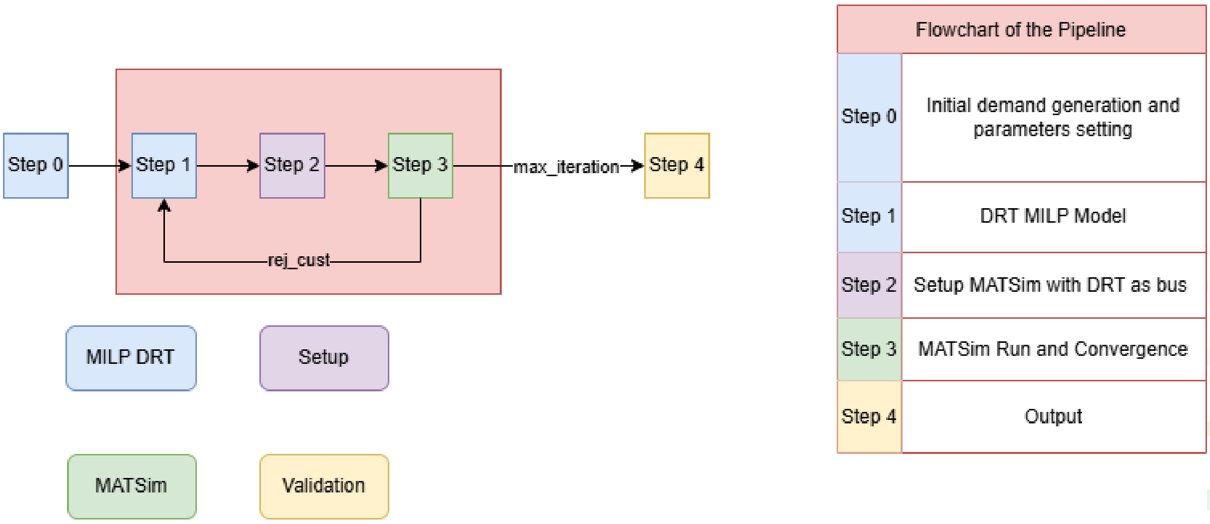

Figure 5.13 the flowchart of pipeline of the MATSim – DRT MILP model integration.

Step 0: Parameter Configuration

In the first step, we set up all the necessary parameters for the simulations. This includes:

- **Number of MATSim Iterations (m-it.)**: How many times the MATSim simulation will run to allow agents to adjust their choices.
- **Number of Pipeline Iterations (p-it.)**: How many times we loop through the entire process to refine the DRT routes.
- **Configuration files**: this file manages the above-mentioned iterations and other parameters, such as criteria convergence threshold, path to different files and so on.
- **Source Files**: All the input files required for the pipeline to operate, such as network data, demand data, and configuration settings.

Step 1: Running the DRT Optimization Model

We begin by running a DRT MILP model. The input for the model should be specified externally. The outputs of model are the routes and itineraries of the DRT that will be exported to the MATSim as input. The details of input and output data are specified below.

- **Input Data**: Customer information, including their preferred departure times, pickup locations, and destinations.

- **Output**: Optimized bus schedules and customer itineraries aimed at improving routes and reducing operational costs.

Step 2: Preparing Data for MATSim Simulation

This step serves as a bridge between the DRT MILP model and the MATSim simulation environment. As the output of Step 1 are incompatible with the MATSim environment, this step involves converting all relevant data into a format that MATSim can use. There are two main parts:

Step 2.1: Generating the "DRT Bus"

The goal is to model DRT service as a traditional bus in MATSim. To achieve this, we get the data from the optimized routes in Step 1, including transit stops, route endpoints, and even recharging stops. These routes are then projected into the reference network, and each transit stop, and route is connected using Dykstra algorithm, as per the current implementation, to find the optimal route between the pickup and drop-off point. This has been done as the metaheuristic used in the Case Study computes the routes for each bus by using this algorithm, in order to achieve as much adherence to the model. Once this is done, we transform these data into MATSim-friendly files. Is important to note the same number of vehicles determined in Step 1, p-it. 1 is used also in Step 4 to ensure consistency.

Step 2.2: Creating the Synthetic Population

After generating the routes, we create a synthetic population based solely on customer demand; no additional demand expansion or external population is included. In Step 3, the agents assigned to the DRT service are given the mode "drt bus" in their initial travel plans, directing them to use the fixed-route DRT bus service. The plan will also include information such as bus line assignment, pickup time, pickup station and so on. In Step 4, the same agents are assigned the mode "drt," in accordance with MATSim's DRT module requirements.

Step 3: Simulating DRT Routes in MATSim

This step runs a MATSim simulation to test the generated DRT routes coming from Step 2 and observe how they perform when users make their own travel choices. The objective is to evaluate whether the optimized DRT routes from Step 1 remain effective when considering that other users might choose different modes of transport, alter their routes, or make different travel decisions. After the simulation, we categorize the agents based on their choices: agents who used the DRT bus to reach their destination are considered *satisfied* with the service and become the "customers" for the next pipeline iteration (**p-it.** i**+1**); agents who did not choose the DRT bus are instead rejected and are fed back into Step 1 for re-optimization in the next iteration. This iterative process continues, refining the DRT routes based on user satisfaction until we reach either the maximum number of pipeline iterations or a convergence criterion.

Step 4: Post-Processing and Analysis

The final step involves analysing the results post-processing. We begin by computing outputs by gathering results from the different pipeline iterations, calculating key performance indicators (KPIs), assessing metrics such as user satisfaction levels, operational efficiency, and cost-effectiveness.

Pilot Visualisation

The tasks originally assigned to NMK are currently being reassigned to other partners, following an amendment to the grant agreement.

5.4. Other activities and Achievements

Stakeholder meeting

The stakeholder meeting was scheduled to take place on **14th November 2024**. Several stakeholders from local authorities and transport service operators were invited. The workshop served as a key platform for gathering feedback, discussing progress, and aligning future actions (e.g., creating the experiments scenarios for simulation experiments) with external perspectives.

5.5. Alignment with Timeline

All activities have been progressing as planned, as shown in Figure 5.1 and Table 5-1 Activities (in red the changes wrt the original plan)

Activity	Description	Planned Execution period	Status
1	Start data collection from shuttle. Start online data collection: live transport information, weather etc. Start the shuttle service using manually driven (electric) shuttle buses. ~~Data collection for digital twin [NMK]~~ Drone data collection is delayed due to NMK replacement. This is not affecting other data collection or activities due for this period in the pilot.	01/03/2024 - 31/12/2024	On time (except for the drone data collection) NMK left the consortium, and their tasks are being reassigned to other partners following an amendment submitted to the European Commission.
2	Analysis of collected data. Plan potential extension & improvement of service (to additional stops): design Phase 2	01/1/2025 - 31/05/2025	Started in advance
3	Modelling: demand forecasting [Task 3.2]	01/1/2025 - 31/05/2025	No delay expected
4	Phase 2	01/03/2025 - 30/09/2025	No delay expected
5	Calibrate simulation model(s)	01/10/2025 – 30/01/2026	No delay expected

Table 5-2 Input items

Item	Description	Planned Execution period	Status
1	WP2: might need to know if there is a data template we should comply with.	01/2025	No delay expected
2	WP3: demand modelling/forecasting	03/2025	No delay expected
3	WP3: Task 3.3 calibration of simulation models deployed in WP5	06/2025	No delay expected

Table 5-3 Output items

Item	Description	Planned Execution period	Status
1	Service data, Demand data, Vehicle data. -> WP3 for developing models [Task 3.2 & 3.3] -> WP2 to be integrated into the data fusion framework [Task 2.2]	09/2024	Data has not been required from WP3 and WP2 in September 2024. We will provide the data upon their requests
2	NMK data -> WP5 - Drone data collection (expected for 2025) is expected to be delayed due to NMK replacement. (see Table 5.1). Collection is now expected to be done in mid-2025.	09/2024 (expected Jun 2025)	NMK left the consortium, and their tasks are being reassigned to other partners following an amendment submitted to the European Commission.
3	Outputs sent to WP6 for synthesis	12/2025	No delay

Table 5-1 to Table 5-3. These tables also give detailed updates on the current status of each activity, the expected input from other WPs (see Table 5-2) and planned outputs to other WPs (see Table 5-3).

Bankruptcy of NAVYA who were tasked with running the autonomous shuttle in Contern required the pilot description to be amended; it is now described in Section 5.1 and comprises two pilot locations with the autonomous shuttle located in Esch. The University of Luxembourg (UniLu), LIST, and the Project Officer are currently in discussions to finalize this amendment. Despite these changes, no delays to the Luxembourg pilot are anticipated.

6. Integration with the Digital Twin

LIST is actively developing the ACUMEN Digital Twin with different features meant to be demonstrated or tested in the pilots, designed with a microservices architecture. The services within this architecture are organized into key categories: Data Ingestion and Processing, Data Storage, Simulation and Modelling, and Visualization.

Currently, LIST has completed the development of the data platform for the DT. This platform enables users to upload and download data seamlessly. Additionally, the API gateway has been finalized, allowing the integration of modules from WPs 2, 3, and 4 into the Digital Twin through simple API development. With these two modules in place, it is now possible for pilot teams and component owners to upload data and connect their modules to the Digital Twin.

The current development focus is on the 2D trajectory visualization module and the scenario management module, both of which are expected to be completed in the coming weeks. Regarding visualization, LIST and AIMSUN have defined a specific format for trajectory files to standardize data input. Additional file formats are planned to be shared with partners in the coming weeks to support the visualization of KPIs, charts, matrices, heatmaps, etc.

Regarding deployment, an instance has been set up per pilot, allowing members of the pilot teams to conduct tests and upload/download data. As an example, the data fusion module developed by AALTO is in an advanced stage of integration. These instances per pilot are available at

- https://acumen-helsinki.list.lu/portal,
- https://acumen-amsterdam.list.lu/portal,
- https://acumen-luxembourg.list.lu/portal and
- https://acumen-athens.list.lu/portal.

The next stages of the Digital Twin development will focus on integrating the majority of modules developed in WPs 2, 3, and 4 to make them accessible for the pilot teams. To support this, API specifications have been provided to the module owners, who are now responsible for developing the necessary APIs on their side for integration.

7. Conclusions

This deliverable is meant to be an interim document for reporting the progress of the four pilots.

The structure of the document has been carefully designed and chosen to allow the reader to collect information on the main dimensions where the activities have taken place, and the link with the other WPs, in particular WP2 (Data), WP3 (Models) and WP4 (Management), and their interaction with WP5 (Integration within the Digital Twin).

The document has also, when applicable, reported the deviations from the original plan, and from the first deliverable D6.1. Section 1.1 has been dedicated to this aspect, whereas Section 1.2 has recalled the pilots' dependency to the other WPs.

Focusing on the Athens pilot, the activities have followed the plan, with substantial progresses in the data collection activities, in particular with the drones' experiment performed in 9 locations in the city, and in the forecasting model developments.

The Helsinki pilot has reported some adjustments in the timeline with respect to Deliverable 6.1. Updates of the timelines for the three phases have been provided. Data collection has also been the main activity with two drone experiment campaigns. Moreover, additional data has been extracted by the mobile app used for the pilot purposes, the Bluetooth and traffic counting sensors. Focusing on the model developments, progressing in the data fusion aspects (WP2) and simulation are also documented.

The Amsterdam pilot is smoothly progressing with no deviations. In particular, the main activities have concentrated on the development of the SUMO simulation platform, whereas data collection has been limited to gathering data from the partner HERE and the open loop detector data made available by the City of Amsterdam.

The Luxembourg pilot has reported some deviations caused by NMK leaving the consortium due to the company's bankruptcy. An amendment has been requested to the European Commission and the process of replacing the partner and reallocating and repurposing the activities planned that involved NMK are at the time of writing still ongoing. This issue has partly also affected the data collection and generation that was supposed to be done by NMK on the site, and that should have been used to create the 3D model within the Digital Twin. Activities have been concentrated on the development of the mobile app for booking and communication between service and customers, the preliminary baseline data collection (mobility and satisfaction survey, passengers data of the current scheduled service), and the agent-based simulation model development for simulating the seamless on-demand service integrated with the train schedules, which has been starting well ahead of time with respect to the original plan.

Finally, an overview and summary of the activities initiated and connected to the Digital Twin have been reported in Section 7.

This document will be updated in Month 27, when all pilots will terminate all activities.