Fleet and traffic management systems
for conducting future cooperative mobility

D5.1 Validation Strategy and Plan

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Primary Author(s)	François Brambati, Nikolas Giampaolo, Elisa Spiller, Paola Lanzi | Deep Blue
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CONTRIBUTORS

Name	Organization	Name	Organization
Emmanouil Nisyrios	NTUA	Patricija Virtič	GoOpti
Konstantinos Katzilieris	NTUA	Katja Saje	GoOpti
Matina Lai-Ying Chau	NTUA	Matej Polzelnik	JSI
Konstantinos Gkiotsalitis	NTUA	Raquel Sánchez	Nommon
Eleni Vlahogianni	NTUA	Oliva García Cantú	Nommon
Oskar Eikenbroek	UT	Leire Serrano	UDeusto
Zakir Farahmand	UT	Alenka Pavlic	Ridango
Athina Tympakianaki	Aimsun	Arslan Ali Syed	TUM

FORMAL REVIEWERS

Name	Organization	Date
Samuel Rouquette	BAX	26-04-2024
Raquel Sánchez	Nommon	26-04-2024
Oliva García Cantú	Nommon	26-04-2024
Matej Polzelnik	JSI	26-04-2024

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1 EXECUTIVE SUMMARY

This deliverable **D5.1 Validation Strategy and Plan** reports the first output of Task 5.4 “Validation plan and results” of the CONDUCTOR project, which aims to design, integrate, and demonstrate advanced traffic and fleet management for efficient and optimal transport of passengers and goods. D5.1 serves as a roadmap for evaluating the effectiveness of the CONDUCTOR project solutions and is strictly interrelated to D5.3 Report on Use cases execution and their validation.

The deliverable includes the detailed validation strategy of the CONDUCTOR project and the validation plans adopted by each Use Case (UC) of the project, describing:

- Overall objectives: the goals that the CONDUCTOR project aims to achieve.
- Key Performance Areas (KPAs): which represent the overarching areas of performance that are relevant to the CONDUCTOR project's success.
- Validation objectives: the specific goals mapped on the KPAs that the project aims to achieve through the validation process.
- Detailed validation objectives (hypotheses): which offer more granular propositions about the project's outcomes.
- Key performance indicators (KPIs): the KPAs’ measurable metrics, allowing for a data-driven assessment of the project's effectiveness.
- Success criteria: the specific benchmarks that need to be met for the UCs to be considered successful.
- Data collection methods: the specific approaches used to gather information throughout the validation process, in order to ensure that the data collected is relevant and reliable for evaluating the project's achievements.
- Validation exercises planning: the list of activities per each validation exercise, comprising responsible partners, timelines, and interrelations.
- Stakeholders’ involvement: the complete list of stakeholders per each UC, as well as their involvement and expectations related to the validation exercises.

D5.1 establishes objectives, measurement methods, and success criteria to assess the project's impact on social, technical, economic, environmental, human performance, and liability aspects.

Keywords: CCAM, Validation Strategy, Validation Plan, Social impacts of innovation; Technical impacts of innovation

2 INTRODUCTION

2.1 Purpose of the document

D5.1 Validation Strategy and Plan document describes the validation activities foreseen in the project coherently with Technology Readiness Levels (TRLs) achieved by the different CONDUCTOR solutions. D5.1 Validation Strategy and Plan presents the validation strategy and plan approach, the stakeholders' expectations and involvement, validation objectives, KPAs, KPIs, success criteria, data collection methods, validation assumptions, validation exercise list, and validation exercise planning. The validation strategy and plan will be used in different phases of the project and for diversified purposes. More specifically, the validation strategy and plan will be used in:

- **T5.1, 5.2, 5.3 – "Use cases"** for the design and validation of the UCs covered by CONDUCTOR.
- **T5.4 – "Validation plan and results"** for the measurement of the KPIs and the overall qualitative and quantitative results obtained by the UCs.
- **T5.5 – "Impact Assessment"** for the expected benefits of the different solutions for each stakeholder of the UCs.

2.2 Intended readership

This document is intended for various stakeholders in the Connected and Cooperative Automated Mobility (CCAM) community at large, especially those involved in the Horizon Europe Work Programme. These include:

- CONDUCTOR consortium members who will need to prepare and execute the validation activities.
- CCAM programme management, and related CCAM projects.
- Academic research and Industrial research who wish to learn about the validation activities behind the CONDUCTOR solutions.

2.3 Structure of the document

The document is structured in 5 sections, articulated as follows:

- **Section 1** presents the executive summary of the document with key information regarding the validation strategy and plan.
- **Section 2** describes the purpose of the document, the intended readership, and structure of the document.
- **Section 3** describes the shared Validation Strategy and, for each of the 3 UCs (5 pilot projects), the stakeholders' expectations and involvement, validation objectives (i.e., including KPAs, KPIs, success criteria, and data collection methods), validation assumptions, validation exercise list, and validation exercise timeline.
- **Section 4** describes, for each of the 3 UCs (5 pilot projects), each validation plan and related exercises in detail.
- **Section 5** includes the list of references used in developing D5.1 Validation Strategy and Plan.

3 VALIDATION STRATEGY AND PLAN

3.1 Validation strategy and plan approach

The following sub-section provides a description of the Validation Strategy and Plan adopted in CONDUCTOR.

The main aim of CONDUCTOR is to design, integrate and demonstrate advanced, high-level traffic and fleet management that allows efficient and globally optimal transport of passengers and goods, while ensuring seamless multimodality and interoperability, through dynamic balancing and priority-based management of vehicles (automated and conventional).

The validation activities are pivotal for the developed solutions in order to establish their fitness for purpose [1]. In the context of CONDUCTOR, a shared strategy among the different Use Cases (UCs) ensures a coordinated validation process as each UC covers different objectives (Table 1). The shared strategy is intended to ensure a robust and generalizable set of results that demonstrate the effectiveness of the project's solutions under research.

An additional benefit of sharing a common overall strategy, consists in the fact that the validation process can be streamlined, maximising resource allocation among relevant partners, and providing the researchers a comprehensive overview of the validation activities, thus providing a more holistic evaluation of the results.

The CONDUCTOR validation strategy is underpinned by a User-Centred Design [2] iterative approach to the development of the CONDUCTOR solutions, placing users' and stakeholders' needs and requirements at the centre of the developed solutions.

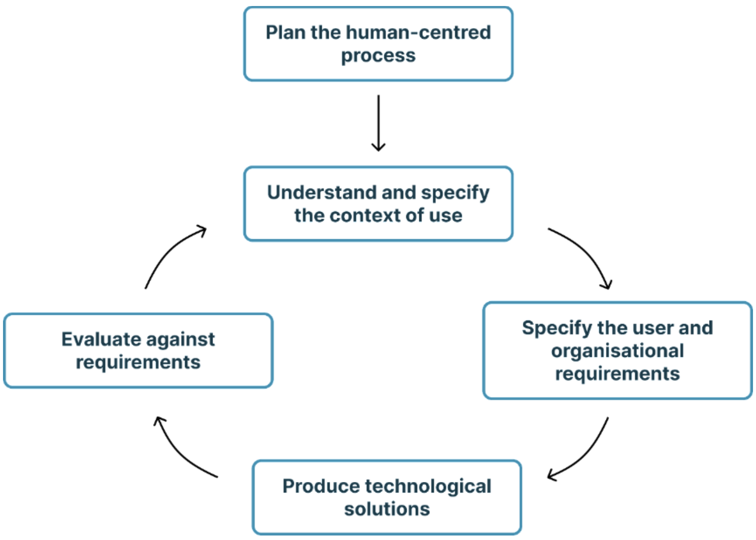

Figure 1 - Graphical representation of how User-Centred Design activities are linked together

The User-centred design process commenced at the beginning of the CONDUCTOR project in Work Package (WP) 1. A careful analysis of the UCs covered by CONDUCTOR, as well as the identification of all relevant stakeholders' and users' needs collected from a State-of-the-Art Review and a dedicated survey, allowed to produce a set of general regulatory (e.g., organisational) and social requirements (i.e., end-users and stakeholders) [3]. Furthermore, the careful specification of the UCs from the context-dependent system requirements was performed by providing an in-detail description of the functionalities of the system, understandable even for stakeholders without deep knowledge about the system under consideration, as well as their related KPIs [4]. WP2, WP3, and WP4 constitute the continuation of the User-centred design approach as they managed the development of the technological solutions. Specifically, WP2 is dealing with the adaptation and implementation of the Models (traffic management, fleet management, inter/multi-modality, interoperability, simulation models, governance models) to CCAM; WP3 is dealing with the selection and implementation of Methods (for data gathering & harmonisation, data fusion & analysis, network load balancing, dynamic optimisation, anomaly detection) for supporting CCAM; and WP4 is dealing with the integration of services and tools to allow CCAM. Lastly, in the User-centred design approach, the present deliverable D5.1 of WP5 constitutes the continuation of these activities as it deals with the validation of the technological solutions developed in the previous WPs.

3.2 Use Cases

The CONDUCTOR UCs are demonstrated in five pilot projects throughout Europe, with each pilot project testing specific functionalities using real-world data. Based on their functionalities, the pilot projects are categorised based on umbrella use cases as follows:

- **UC1**: Integrated Traffic Management with Inter-Modality
    - **UC1 Athens** pilot project (Greece) involves the optimal synchronization of buses and light rail (tram), metro, and trolley-bus services by adjusting schedules to reduce door-to-door travel times and using traffic management and journey planning platforms to improve the reliability and flexibility of multi-modal journeys.
    - **UC1 Almelo** pilot project (The Netherlands) deals with conditional priority for freight traffic along a major logistics corridor to reduce the number of stops at traffic lights and thereby improve traffic circulation throughout the network.
    - **UC1 Madrid** pilot project (Spain) considers traffic management to accelerate network recovery after planned and unplanned events in the context of the transition towards a traffic composition with a larger share of connected and automated vehicles that can communicate with their surroundings and with a traffic management centre directly.
- **UC2**: Demand-responsive transport
    - **UC2** – Slovenia pilot project (Slovenia) deals with the long-term optimisation and continuous refinement of route plans for demand-responsive transport (DRT) services in the context of shuttle operations.
- **UC3**: Urban Logistics
    - **UC3** – Madrid pilot project (Spain) considers solutions for last-mile parcel delivery based on the integration of the urban distribution of goods with demand-responsive transport services enabled by CCAM, thereby improving utilisation of under-utilised services during off-peak hours.

3.3 Overall objectives

A comprehensive table (Table 1) summarizes the CONDUCTOR project's **overall objectives** related to each UC and pilot project. The table provides an overview of how each UC contributes to the overall validation results of the CONDUCTOR project.

Table 1 - Project objectives and related Use Cases

Objective	Use Case	How
O1: To demonstrate traffic and fleet management to integrate CCAM for people and goods	UC1 Athens, UC1 Almelo, UC1 Madrid, UC2 UC3	The upgraded traffic and fleet management systems within different demonstrating cities will show their capability to deal with the increasing number of autonomous vehicles. The demonstrations, through mixed traffic orchestration, will mostly rely on public transportation, as the amount of private autonomous cars is still expected to be relatively low. The main driving force in demonstrations will be the consideration of users' social needs. Within the upgraded fleet simulation environment, we aim to investigate fleet management scenarios for a multipurpose transport system combining passengers and goods transportation. We will also evaluate the impacts on traffic efficiency and environmental effects.
O2: To address intermodal interfaces and interoperability between traffic management systems	UC1 Athens	The multi-modal system (combining different transportation modes) will be optimised based on the user needs to ensure transport resilience and business continuity.
O3: To test and demonstrate advanced simulation models in real-life traffic conditions considering different priorities	UC2, UC3	The fleet control model (including public transit and logistics) will be coupled with a multi-resolution traffic simulation model to evaluate network-wide effects of the implemented fleet management strategies for demand-responsive mobility services for people and goods. Furthermore, the relevant introduced parameters will help to quantify the trade-off between the user needs and the system's technical optimality.
O4: To demonstrate optimised mobility network load balancing	UC3	The proposed idea of ride-parcel-pooling aims at utilising unused capacities by combining passengers and goods transportation flows within one transport system. We will also implement and evaluate cooperative routing strategies (social routing) for large scale CCAM vehicle fleets and aim at balancing the traffic loads on the overall road network. The evaluation will be assessed using an upgraded simulation environment.

O5: To consider governance of the traffic management system considering user needs	UC2 UC3	The use of advanced simulation environments, coupled with traffic management solutions introduced in CONDUCTOR, allow for the evaluation of regulation strategies concerning DRT. DRT mobility services include multi-scale restrictions in parts of the transportation network (link restriction – local level up to zone restriction – network level) as well as the introduction of dynamic priority lane allocation based on current and future/forecasted performance of transport networks.

CONDUCTOR fosters a shared strategy among all UCs to demonstrate the effectiveness of the developed solutions in reaching the project's goals, as well as measuring the impact on the KPIs and collect end-user feedback to check the results against the identified needs and requirements.

3.4 Validation objectives

The following table (Table 2) describes the **KPAs** identified as relevant for the project. In the following these KPAs are mapped into low level **validation objectives** specific for each UCs.

Table 2 - CONDUCTOR Key Performance Areas and Validation Objectives

KPA	Validation Objectives
Technical	To validate that the CONDUCTOR solutions enable an optimal exploitation of transport of passengers and goods.
Social	To investigate whether the CONDUCTOR solutions have positive effects on the wellbeing of passengers and stakeholders.
Environmental	To investigate whether the CONDUCTOR solutions have positive effects on the environmental impact of the transport of passengers and goods.
Economic	To investigate that the CONDUCTOR solutions enable a sustainable cost-benefit balancing for the transport of passengers and goods.
Human Performance	To validate that the CONDUCTOR solutions do not negatively impact the required Human performance levels for the transport of passengers and goods.
Liability	To determine that the CONDUCTOR solutions do not introduce unacceptable liability risks for operators and stakeholders.

The CONDUCTOR project's overall objectives are investigated by looking at the impact of the solutions on the different KPAs.

- **O1** is investigated by looking at the impact of solutions on the following KPAs: Technical, Social, Environmental, Economic, Human Performance, Liability.
- **O2** is investigated by looking at the impact of solutions on the following KPAs: Technical, Social, Economic, Human Performance, Liability.

- **O3** is investigated by looking at the impact of solutions on the following KPAs: Technical, Social, Economic, Human Performance, Liability.
- **O4** is investigated by looking at the impact of solutions on the following KPAs: Technical, Social, Human Performance, Liability.
- **O5** is investigated by looking at the impact of solutions on the following KPAs: Technical, Social, Human Performance, Liability.

These KPAs are declined for different validation exercises through the validation objectives. The following sub-sections will report the validation objectives for each UC.

3.4.1 Validation objectives – UC1 Athens

The following sub-section (Tables 3-4) presents the **KPAs**, **Validation objectives**, **detailed validation objectives**, **success criteria**, **KPIs**, and **data collection methods** related to the UC1 Athens pilot project.

Table 3 - UC1 Athens detailed validation objectives

KPA	Validation Objectives	Detailed validation objectives
Technical	To validate that the CONDUCTOR solutions enable an optimal exploitation of transport of passengers and goods.	The solution reduces passengers' travel time
		The solution improves service reliability
		The solution reduces the travel time of vehicles
Social	To investigate whether the CONDUCTOR solutions have positive effects on the wellbeing of passengers and operators.	The solution improves service accessibility
Environmental	To investigate whether the CONDUCTOR solutions have positive effects on the environmental impact of the transport of passengers and goods.	The solution reduces Greenhouse Gas (GHG) emissions (CO_2, NO_x)
Economic	To investigate that the CONDUCTOR solutions enable a sustainable cost-benefit balancing for the transport of passengers and goods.	The solution reduces passengers' costs.
Liability	To determine that the CONDUCTOR solutions do not introduce unacceptable liability risks for operators and stakeholders.	Liability risks are acceptable for the concerned operators and stakeholders

Table 4 - UC1 Athens KPIs and data collection methods

KPA	Detailed validation objectives	KPIs	D1.3 KPIs	Success criteria	Data collection methods
Technical	The solution reduces passengers' travel time	Average travel time per passenger, Waiting time of passengers	UC1_T01; UC1_T04	By at least 3 minutes	Simulation
	The solution improves service reliability	Punctuality of scheduled arrival/departure time	UC1_T03	Within 5 minutes	Real data for the current scenario and simulation
	The solution reduces the travel time of vehicles	Travel time and speed of vehicles	New	Reduction of the average vehicle travel time by 5%	Simulation
Social	The solution improves service accessibility	Travel times	UC1_T01	Reduction of door-to-door travel time by at least 3 minutes	Simulation
Environmental	The solution reduces GHG emissions (CO_2, NOx)	Total emissions by all the vehicles in the network who have completed their trip (CO_2, NOx)	New	Reduction of CO_2 and NOx emissions by 5%	Simulation
Economic	The solution reduces passengers' costs.	Running costs per passenger (fuel / energy consumption)	UC1_B01	Reduction of fuel related costs by 5%	Simulation
Liability	Liability risks are acceptable for the concerned operators	Liability risks for operators are adequately identified and considered	New	Liability risks for operators are adequately mitigated (if needed)	Legal case

	and stakeholders	Liability risks for organisations are adequately identified and considered	New	Liability risks for organisations are adequately mitigated (if needed)	
		Liability risks for manufacturers are adequately identified and considered	New	Liability risks for manufacturers are adequately mitigated (if needed)	

3.4.2 Validation objectives – UC1 Almelo

The following sub-section (Tables 5-6) presents the **KPAs**, **Validation objectives**, **detailed validation objectives**, **success criteria**, **KPIs**, and **data collection** methods related to the UC1 Almelo pilot project.

Table 5 - UC1 Almelo detailed validation objectives

KPA	Validation Objectives	Detailed validation objectives
Technical	To validate that the CONDUCTOR solutions enable an optimal exploitation of transport of passengers and goods.	The solution increases (traffic signal) capacity
		The solution establishes a governance model regarding prioritisation
Social	To investigate whether the CONDUCTOR solutions have positive effects on the wellbeing of passengers and operators.	The solution improves citizens' wellbeing
		The solution improves road safety
Environmental	To investigate whether the CONDUCTOR solutions have positive effects on the environmental impact of the transport of passengers and goods.	The solution reduces GHG emissions (including CO2, NOx)
		The solution improves air quality
		The solution reduces sound power
Economic	To investigate that the CONDUCTOR solutions enable a sustainable cost-benefit balancing for the transport of passengers and goods.	The solution reduces fuel consumption
		The solution improves service reliability
		The solution improves efficiency of (logistic) services

Human Performance	To validate that the CONDUCTOR solutions do not negatively impact the required Human performance levels for the transport of passengers and goods.	The role of the human is consistent with human capabilities and limitations
		Technical systems support the human operators in performing their tasks
Liability	To determine that the CONDUCTOR solutions do not introduce unacceptable liability risks for operators and stakeholders.	Liability risks are acceptable for the concerned operators and stakeholders

Table 6 - UC1 Almelo KPIs and data collection methods

KPA	Detailed validation objectives	KPIs	D1.3 KPIs	Success Criteria	Data collection method
Technical	The solution increases (traffic signal) capacity	The (maximum) discharge rate in vehicle per second (veh/s)	New	5% increase in maximum discharge rate	Simulation and real-world measurements
	The solution establishes a governance model regarding prioritisation	Establishment signal control policy	New	New policy for prioritising target groups	Survey, interviews
Social	The solution improves residents' wellbeing	Total noise emitted, total emissions by all vehicles, sound power level of vehicles	UC1_E03; UC1_E04	10% reduction of stops	Simulation and real-world measurements
	The solution improves road safety	Number of red-light negations	UC1_E05	TBD	Real-world measurements
Environmental	The solution reduces GHG emissions (including CO_2, NO_x)	Total emissions by all vehicles in the network under consideration	UC1_E03	Reduction of CO_2 and NO_x emissions by 5%	Simulation and real-world measurements

	The solution improves air quality	Reduction in fuel consumption	UC1_B03	Reduction of fuel consumption by 5%	Simulation and real-world measurements
	The solution reduces noise pollution	The number of stops made by trucks/Heavy-duty vehicles (HDVs)	UC1_E04	10% reduction in stops	Simulation and real-world measurements
Economic	The solution reduces fuel consumption	The number of stops made by trucks/HDVs	UC1_B03	10% reduction in stops	Simulation and real-world measurements
	The solution improves service reliability	Average and 95th percentile in travel times for trucks/HDVs	UC1_T11	5% decrease in travel time	Simulation and real-world measurements
	The solution improves efficiency of (logistic) services	Delay by trucks/HDVs: additional travel time compared to an uninterrupted pass	UC1_T11 UC1_T13	5% decrease in delay	Simulation and real-world measurements
Human Performance	The role of the human is consistent with human capabilities and limitations	Messages by application are understood, and can be complied with	New	Positive feedback from participants and stakeholders	Survey, interviews
	Technical systems support the human operators in performing their tasks	Perceived delays and travel times,	New	Positive feedback from participants and stakeholders	Survey, interviews
Liability	Liability risks are acceptable for the concerned operators and stakeholders	Liability risks for operators are adequately identified and considered	New	Liability risks for operators are adequately mitigated (if needed)	Legal case

		Liability risks for organisations are adequately identified and considered	New	Liability risks for organisations are adequately mitigated (if needed)	
		Liability risks for manufacturers are adequately identified and considered	New	Liability risks for manufacturers are adequately mitigated (if needed)	

3.4.3 Validation objectives – UC1 Madrid

The following sub-section (Tables 7-8) presents the **KPAs**, **Validation objectives**, **detailed validation objectives**, **success criteria**, **KPIs**, and **data collection methods** related to the UC1 Madrid pilot project.

Table 7 - UC1 Madrid detailed validation objectives

KPA	Validation Objectives	Detailed validation objectives
Technical	To validate that the CONDUCTOR solutions enable an optimal exploitation of transport of passengers and goods.	The solution reduces travel times and delays
		The solution improves network recovery time in cases of events/incidents.
Social	To investigate whether the CONDUCTOR solutions have positive effects on the wellbeing of passengers and operators.	The solution improves travel time/delays due to network disruptions
Environmental	To investigate whether the CONDUCTOR solutions have positive effects on the environmental impact of the transport of passengers and goods.	The solution reduces GHG emissions (CO_2, NO_x)
Economic	To investigate that the CONDUCTOR solutions enable a sustainable cost-benefit balancing for the transport of passengers and goods.	The solution reduces economic losses due to travel delays
Human Performance	To validate that the CONDUCTOR solutions do not negatively impact the	The role of the human is consistent with human capabilities and limitations

	required Human performance levels for the transport of passengers and goods.	Technical systems support the human operators in performing their tasks
Liability	To determine that the CONDUCTOR solutions do not introduce unacceptable liability risks for operators and stakeholders.	Liability risks are acceptable for the concerned operators and stakeholders

Table 8 - UC1 Madrid KPIs and data collection methods

KPA	Detailed validation objectives	KPIs	D1.3 KPIs	Success Criteria	Data collection methods
Technical	The solution reduces travel times and delays	Average travel times and delays per connected and conventional vehicles	UC1_T06; UC1_T09	Decrease of traffic queue length reduction by 10%-20% Increase of average mean speeds	Traffic simulation
	The solution improves network recovery time in cases of events/incidents.	Different traffic measurements will be analysed to capture the recovery time, in terms of reducing congestion and bringing the network back to normal conditions.	UC1_T08		

Environmental	The solution reduces GHG emissions (CO_2, NOx)	Total emissions by all the vehicles in the network who have completed their trip (CO_2, NOx)	UC1_E02	Ensure that the interventions do not have negative implications with respect to total emissions by minimizing the congestion and delay time impacts due to network disruptions	Traffic simulation
Social	The solution improves travel time/delays due to network disruptions	Total travel time/delays due to network disruptions	New	Positive feedback from stakeholders	Stakeholder feedback
Economic	The solution reduces economic losses due to travel delays	Total travel times and delays	UC1_B02	Economic impact can be studied indirectly by analysing the total travel delays. The proposed solutions aim to reduce travel delays	Traffic simulation
Human Performance	The role of the human is consistent with human capabilities and limitations	Human performance risks for operators are adequately identified and considered	New	Positive feedback from stakeholders	Stakeholder feedback
	Technical systems support the human operators in performing their tasks	Technical risks for operators are adequately identified and considered	New	Positive feedback from stakeholders	Stakeholder feedback

Liability	Liability risks are acceptable for the concerned operators and stakeholders	Liability risks for operators are adequately identified and considered	New	Liability risks for operators are adequately mitigated (if needed)	Legal case
		Liability risks for organisations are adequately identified and considered	New	Liability risks for organisations are adequately mitigated (if needed)	
		Liability risks for manufacturers are adequately identified and considered	New	Liability risks for manufacturers are adequately mitigated (if needed)	

3.4.4 Validation objectives – UC2

The following sub-section (Tables 9-10) presents the **KPAs**, **Validation objectives**, **detailed validation objectives**, **success criteria**, **KPIs**, and **data collection methods** related to UC2 pilot project.

Table 9 - UC2 detailed validation objectives

KPA	Validation Objectives	Detailed validation objectives
Technical	To validate that the CONDUCTOR solutions enable an optimal exploitation of transport of passengers and goods.	The solution optimises human interventions
		The solution optimises route plans
Social	To investigate whether the CONDUCTOR solutions have positive effects on the wellbeing of passengers and operators.	The solution improves accessibility to services
Environmental	To investigate whether the CONDUCTOR solutions have positive effects on the environmental impact of the transport of passengers and goods.	The solution reduces GHG emissions (CO2, NOx)
Economic	To investigate that the CONDUCTOR solutions enable a sustainable cost-	The solution reduces fuel consumption

	benefit balancing for the transport of passengers and goods.	The solution reduces operational costs
		The solution enables new services
Human Performance	To validate that the CONDUCTOR solutions do not negatively impact the required Human performance levels for the transport of passengers and goods.	The role of the human is consistent with human capabilities and limitations
		Technical systems support the human operators in performing their tasks
Liability	To determine that the CONDUCTOR solutions do not introduce unacceptable liability risks for operators and stakeholders.	Liability risks are acceptable for the concerned operators and stakeholders

Table 10 - UC2 KPIs and data collection methods

KPA	Detailed validation objectives	KPIs	D1.3 KPIs	Success Criteria	Data collection methods
Technical	The solution optimises human interventions	Rate of manual interventions for shuttle service route plans	UC2_T02	50% less manual actions per planner	Logs from the Demand Responsive Transport Platform (DRP) on the real-world data. comparing the manual planning and software assisted planning
	The solution optimises route plans	Fleet kilometres per daily plan	UC2_T01	3 km less per plan for passenger custom addresses	Real-world measurement, virtual measurement on the real-world data

Social	The solution improves accessibility to services	Ratio of accepted and rejected requests	UC2_E02	100% increase in bookings between 22:00 and 7:00 hours for bookings for the period between 22:00 and 9:00	Logs from the DRP on the real-world data. Collecting orders for new time windows and checking the platform uptime
Environmental	The solution reduces GHG emissions (CO2, NOx)	Fuel consumption per passenger dropped off	UC2_E01	5 % lesser fuel (l/100km) per passenger	Real-world measurement, virtual measurement on the real-world data; checking the average number of passengers per van and average reduced numbers of kilometres.
Economic	The solution reduces fuel consumption	Average costs per kilometre per passenger dropped off	UC2_B01	5% lesser average cost per kilometres per passenger	Real-world measurement, virtual measurement on the real-world data. checking the average number of passengers per van and average reduced numbers of kilometres.

	The solution reduces operational costs	Average planning costs per route plan	UC2_B02	50% lesser average planning costs	Real-world measurement, virtual measurement on the real-world data; number of people working on plans
	The solution enables new services	Enabled and number of last-minute product sales	UC2_B03	4 new services tested 2 new services used in production	Logs from the DRP and the Real-world measurement, virtual measurement on the real-world data
Human Performance	The role of the human is consistent with human capabilities and limitations	Human performance risks for employees are adequately identified and considered	New	Positive feedback from employees	Questionnaires
	Technical systems support the human operators in performing their tasks	Technical risks for employees are adequately identified and considered	New	Positive feedback from employees	Questionnaires
Liability	Liability risks are acceptable for the concerned operators and stakeholders	Liability risks for operators are adequately identified and considered	New	Liability risks for operators are adequately mitigated (if needed)	Legal case
		Liability risks for organisations are adequately identified and considered	New	Liability risks for organisations are adequately mitigated (if needed)	

		Liability risks for manufacturers are adequately identified and considered	New	Liability risks for manufacturers are adequately mitigated (if needed)	

3.4.5 Validation objectives – UC3

The following sub-section (Tables 11-12) presents the **KPAs**, **Validation objectives**, **detailed validation objectives**, **success criteria**, **KPIs**, and **data collection methods** related to UC3 pilot project.

Table 11 - UC3 detailed validation objectives

KPA	Validation Objectives	Detailed validation objectives
Technical	To validate that the CONDUCTOR solutions enable an optimal exploitation of transport of passengers and goods.	The solution improves operational efficiency
		The solution increases road capacity
Social	To investigate whether the CONDUCTOR solutions have positive effects on the wellbeing of passengers and operators.	The solution improves service acceptance
Environmental	To investigate whether the CONDUCTOR solutions have positive effects on the environmental impact of the transport of passengers and goods.	The solution reduces GHG emissions ($CO2$, NOx)
Economic	To investigate that the CONDUCTOR solutions enable a sustainable cost-benefit balancing for the transport of passengers and goods.	The solution reduces operational costs
		The solution reduces fuel consumption
Human Performance	To validate that the CONDUCTOR solutions do not negatively impact the required Human performance levels for the transport of passengers and goods.	The role of the human is consistent with human capabilities and limitations
		Technical systems support the human operators in performing their tasks
Liability	To determine that the CONDUCTOR solutions do not introduce unacceptable liability risks for operators and stakeholders.	Liability risks are acceptable for the concerned operators and stakeholders

Table 12 - UC3 KPIs and data collection methods

KPA	Detailed validation objectives	KPIs	D1.3 KPIs	Success Criteria	Data collection methods
Technical	The solution improves operational efficiency	On-demand passenger's transport fleet utilisation rate	New	Increase in 5%	Optimisation algorithm
		Total distance of the DRT and delivery vehicles	UC3_T01	The increase in travel distance of DRT due to the mixed service (people + parcels) do not exceed the 10% of the distance reduced in delivery vehicles due to the integration.	Traffic simulation
		Number of vehicles used for goods delivery	UC3_T03	Reduction in the number of vehicles by 10%	Optimisation algorithm and traffic simulation
		Idle trips on-demand passenger's transport	New	Reduction by 10%	Optimisation algorithm and traffic simulation
	The solution increases road capacity	Average travel times of road traffic	UC3_T03	Reduction of 10%	Traffic simulation
Social	The solution improves service acceptance	Acceptance of ride-parcel-pooling	UC3_E01	At least 30% of the respondents accept the solution	Survey

		Adherence to passenger travel times	UC3_T10	85%	Optimisation algorithm and traffic simulation
		Uncertainty on parcel's delivery time	UC3_T07	5%-10%	Optimisation algorithm and traffic simulation
		Passenger demand served	UC3_T08	95%	Optimisation algorithm and traffic simulation
		Parcel demand served	New	20%	Optimisation algorithm and traffic simulation
Environmental	The solution reduces GHG emissions (CO2, NOx)	Total vehicle emissions (CO2 and NOx) of delivery vehicles	UC3_E01	5% reduction in CO2 emissions and 10% reduction in NOx emissions	Obtained using equivalence tables assuming different circulating fleets and through traffic simulations to get the kilometres travelled for each scenario
Economic	The solution reduces operational costs	Average costs per parcel delivered & passenger	UC3_B01; UC3_B02	At least 5% of operational cost reduction	Survey

	The solution reduces fuel consumption	Total fuel consumed by the DRT and delivery vehicles	New	The increase in fuel consumption of DRT due to the mixed service (people + parcels) do not exceed 10% of the fuel consumption reduced in delivery vehicles due to the integration	Obtained using consumption tables by vehicle category assuming different circulating fleets and through traffic simulations to get the kilometres travelled for each scenario
Human Performance	The role of the human is consistent with human capabilities and limitations	Human performance risks for operators are adequately identified and considered	New	Positive feedback from stakeholders	Stakeholder feedback
	Technical systems support the human operators in performing their tasks	Technical risks for operators are adequately identified and considered	New	Positive feedback from stakeholders	Stakeholder feedback
Liability	Liability risks are acceptable for the concerned operators and stakeholders	Liability risks for operators are adequately identified and considered	New	Liability risks for operators are adequately mitigated (if needed)	Legal case
		Liability risks for organisations are adequately identified and considered	New	Liability risks for organisations are adequately mitigated (if needed)	

		Liability risks for manufacturers are adequately identified and considered	New	Liability risks for manufacturers are adequately mitigated (if needed)	

3.5 Stakeholders' expectations and involvement

The table below (Table 13) describes the identified stakeholders and their expectations related to the CONDUCTOR solutions under research.

Table 13 - Stakeholders' expectations and involvement

UC	Target group	Type	Expectations	Involvement
UC1 Athens	OASA	**End-users**	Profit from the timetables and the reduced bus travel times due to green light priority.	Actively involved in data provision and pilot support.
	Municipality of Athens	**Impacted group**	Increase the attractiveness of public transport.	TBD
UC1 Almelo	Municipality of Almelo	**Stakeholders**	Profit from the results of the UC1 Almelo.	Actively involved in the set-up, organization, execution and evaluation of the UC1 Almelo pilot.
	Province of Overijssel			
	Logistics representative organisation			
	Ministry of Infrastructure and Water Management			

	Application and cloud service provider			
	Logistics service providers (planners)			
	Truck drivers	**End-users**	Change in procedures and tasks.	Driving behaviour of the truck drivers will be monitored. Engagement and evaluation of drivers' perception and opinions through interviews/surveys/workshops.
	Other road users and residents	**Impacted group**	Impacted by freight signal priority (delays, noise, etc.).	Assessed through data analytics and potentially using surveys.
UC1 Madrid	Madrid Calle 30	**Stakeholders**	Profit from the results of the UC1 Madrid	Participation in workshops and survey for UC definition, specifications, implementation issues. Additional feedback will be collected upon UC1 Madrid results.
	Madrid City Council			
	EMT Madrid			
	HERE			
UC2	Passengers	**Impacted group, End-Users**	Delivery to the destination at the desired time, cheaper transfer service.	The goal is to increase the passengers' satisfaction with timely deliveries as well as with cheaper transfer service. Assessment will be achieved through surveys. Also, the passenger's habits will be assessed through the user order data.

	Shuttle Drivers	**End-Users**	Better working conditions	The shuttle drivers will use a mobile application which will assist them on taking the best route. The evaluation and usage of mobile application will be assessed through workshops and surveys.
	DRT Operators	**Stakeholders**	Improvement in service quality	Regular meetings are held where the edge cases and general implementation of the services are discussed to ensure that new tools are aligned with the actual needs of operators.
UC3	Madrid Calle 30	**Stakeholders**	Profit from the results of the UC3	Participation in workshops and survey for UC definition, specifications, implementation issues. Additional feedback through a dedicated workshop in T5.3 and survey will be collected upon UC3 results.
	Madrid City Council			
	Consorcio Regional de Transportes de Madrid			
	EMT Madrid			
	TRANSyT - UPM			
	Citylogin			
	Arriva			
	Correos			
	End users (both of DRT and last-mile delivery services)	**End-users**		Involved to assess liability and social KPIs by means of surveys distributed among end users.

3.6 Validation assumptions

The following sub-section lists the main **technical** and **operational assumptions** per each pilot project. They are reported in the table below (Table 14).

Table 14 - Validation assumptions

UC	Assumption ID	Validation assumption description	Justification
UC1 Athens	VA01	General traffic conditions do not change	Travel times of the road network do not change because of our actions.
	VA02	Passenger demand remains the same	The passenger demand in the Public Transport network does not change because of our actions.
UC1 Almelo	VA01	Truck drivers will follow the speed advice provided by the signal controllers	Granting signal priority requires drivers' cooperation to achieve the intended objectives.
	VA02	Latency in the data exchange between infrastructure and equipped vehicles is of no consideration	Latency in the data-exchange is inevitable, however, it could be in the range of milliseconds and has no impact on our solutions.
UC1 Madrid	VA01	General traffic demand remains the same	No changes in mode choice will be considered in this analysis due to network disturbances.
	VA02	Consider existing infrastructure for transmitting travel information to all vehicles	Conventional vehicles will follow the information provided by existing Variable Message Signs (VMS) signs.
UC2	VA01	General booking demand remains the same	No significant changes to the booking habits of passengers.
	VA02	No major roadworks on the validation corridors	No major roadworks is expected on each of the three validation corridors (Ljubljana – Trieste Airport, Ljubljana – Zagreb Airport, Maribor – Vienna Airport).
UC3	VA01	Existence of a governance model for service regulation and stakeholders' interaction	A governance model for service organization and regulation is essential to ensure the participation and interaction between key stakeholders.

	VA02	Cooperation between passengers' transport and goods transport services	Cooperation between both services is essential for the UC implementation, if the services are unwilling to collaborate, the UC cannot be implemented.
	VA03	Adaption and authorization of vehicle infrastructures for mix transportation of passengers and goods, identification of new infrastructure needs (which and where), and definition of different delivery modes	With the current Spanish regulation, the mix transportation of passengers and parcels is not allowed, hence, many passenger transport vehicles are not adapted for it. For this UC to be implemented in real life, the regulations must change, and infrastructure needs must be identified (when needed). For that, different delivery modes should be defined, to adapt regulation and infrastructures accordingly.
	VA04	System protection against cyberattacks and attacks to critical infrastructures (such as transport structures). Compliance with high security and cybersecurity standards (e.g., ISO 27001)	As the data needed to define the coordination strategies for this UC are business sensitive and may contain users' personal data, the system must ensure data security and compliance with the GDPR.
	VA05	Regulations or incentives for logistic services to reduce the number of delivery vans and to ensure adoption	It may happen that the solution increases the logistic services costs, but that the socioeconomic benefits of the solution (congestion and emissions reduction) compensate for that increase. In this case, the logistic services shall receive incentives to adopt the solution.

3.7 Validation exercise list

The table below (Table 15) provides the **list of validation exercises**, validation exercise titles, and a brief description of each validation exercise per each UC and pilot project.

Table 15 - Validation exercise list

UC	Validation exercise ID	Validation exercise title	Brief description
UC1 Athens	#01	Cooperative Traffic Management System	Test the Cooperative Traffic Management System, combining dynamic space allocation and traffic signal control to enhance urban transportation.
	#02	Multimodal Fleet Management System	Test the Estimated Time of Arrival (ETA) estimation of buses based on the Multimodal Fleet Management System with incident detection and management
	#03	Vehicle Scheduling Model for Autonomous and Connected Vehicles	Develop and test the Vehicle Scheduling Model for Autonomous and Connected Vehicles (VSMACV), such that the transfer of human mobility and goods is optimised within a dynamic context.
UC1 Almelo	#01	Almelo pilot tests	Test the effects of CCAM functionalities in the context of multimodal traffic management with a specific focus on freight traffic.
	#02	Simulation tests	Investigate the effects regarding scalability of CCAM functionalities and possible extensions for traffic management.
UC1 Madrid	#01	Network impact simulation	Identify and quantify the impacts of planned and unplanned events in the network by analysing adequate measurements to be obtained from the simulation.
	#02	Response plans for planned network events	Compares the baseline scenario with the planned event scenarios after the activation of specific response plans.

	#03	Response plans for unplanned network events	Compare the baseline scenario with the unplanned event scenarios after the activation of specific response plans.
UC2	#01	Demand responsive transport platform and routing optimization	Compare with the baseline scheduling and evaluating reliability of the platform.
	#02	Continuous planning with smart triggers based on events.	Virtual test on the real data with comparison to the base implementation and evaluating the effects of real-time events.
	#03	Demand / booking prediction	Virtual test on the real data with comparison to the continuous planning base implementation.
UC3	#01	Initial integration scenario	Compare the baseline scenario with the initial integration scenario.
	#02	Optimised integration scenario without constraints to delivery time window	Compare the initial integration scenario with the optimized integration scenario without constraints to parcel delivery time windows.
	#03	Optimised integration scenario with constraints to delivery time window	Compare the initial integration scenario with the optimized integration scenario with constraints to parcel delivery time windows.

3.8 Validation exercises timeline

The table below (Table 16) provides a graphical representation of the **validation exercises timeline** per each UC and pilot project. The indicated periods cover pre- during, and post-execution phases. For the specific validation exercises planning refer to the Exercise planning sections (Section 4) of each validation exercise.

Table 16 - Validation exercises timeline

UC	N	Months																	
		18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
UC1 Athens	#01																		
	#02																		
	#03																		
UC1 Almelo	#01																		
	#02																		
UC1 Madrid	#01																		
	#02																		
	#03																		
UC2	#01																		
	#02																		
	#03																		
UC3	#01																		
	#02																		
	#03																		

4 VALIDATION EXERCISES

The following sub-sections provide detailed descriptions of each validation exercise of the 5 pilot projects in terms of: validation exercise description, validation scenarios, validation exercise platform, validation tools and techniques, data collection and analysis, participants, exercise planning, and identified risks and mitigation actions.

4.1 Use Case 1 - Athens

The objective of UC1 – Athens is to showcase novel traffic management strategies for CCAM, emphasizing public transport, such as transit signal priority and dyna VSMACV mic utilisation of bus lanes. Real traffic conditions will be used to demonstrate the ability to support the optimization and balancing of mobility network loads. Collaboration involves NTUA, Aimsun, Ridango, and OASA (public transport authority for the city of Athens).

More specifically, OASA will define the specific scenarios to be executed in the framework of this use case and provide data (supply and demand) for the transit system. NTUA will select project solutions and relevant case scenarios to be simulated within the Athens testbed, provide, calibrate, and integrate solutions in the Athens testbed, and execute the experiments. The results will be analysed in detail by NTUA.

Aimsun will help develop the proposed Application Programming Interface (APIs) to integrate solutions, while Ridango will provide its fleet management solution. The current transit data ETA accuracy will be audited and compared to the accuracy of the improved ETA algorithm outcomes. This UC is interrelated and requires input from Tasks 2.1-2.3 and Task 3.5. The developed components involved in this Use Case are the following: the Cooperative Traffic Management System developed by NTUA, the Multimodal Fleet Management System with incident detection and management developed by Ridango, and the Vehicle Scheduling Model for Autonomous and Connected Vehicles, again developed by NTUA.

The Use Case is carried out for the city of Athens, and in particular, for the Athens inner-ring urban transport network. The objective of the validation exercises is to analyse the impact of the implementation of the different components developed in WP2, for the Athens simulation testbed.

The validation exercises are based on the different components related to this UC and are defined as follows:

1. Validation exercise #01 involves testing the Cooperative Traffic Management System, combining dynamic space allocation and traffic signal control to enhance urban transportation. It aims to replace static Dedicated Bus Lanes with dynamic restrictions, adapting to real-time traffic patterns for increased road capacity, decreased congestion, and a more balanced urban traffic flow.
2. Validation exercise #02 involves testing the ETA estimation of buses based on the Multimodal Fleet Management System with incident detection and management.
3. Validation exercise #03 involves the development and testing of the Vehicle Scheduling Model for Autonomous and Connected Vehicles, such that the multimodal transfer synchronisation of human mobility is optimised within a dynamic context.

4.1.1 Validation exercise #01

This validation exercise will address the **Cooperative Traffic Management System** developed by NTUA in WP2, Task 2.1, for validation in UC1 Athens. This novel system combines the concept of dynamic space allocation with traffic signal control, in an effort to achieve more space-efficient urban transportation systems that are responsive to fluctuating traffic patterns. In practice, this system could potentially eliminate the need for static Dedicated Bus Lanes, instead employing dynamic restrictions on the utilisation of bus priority lanes that adapt to current traffic and public transport needs. This flexibility results in enhanced road capacity, reduced congestion, and a more balanced urban traffic flow, ultimately contributing to a more adaptable and efficient urban environment.

Validation exercise description

In this exercise, NTUA will evaluate the developed Multi-Agent Reinforcement Learning (MARL) controller in the simulation testbed of the city of Athens, and in particular, in Alexandras Avenue. The MARL controller will engage with the simulation in real-time, taking control of all traffic signals across Alexandras Avenue, as well as managing the vehicle density within bus priority lanes, in order to enhance traffic flow without compromising transit performance. The objective of this exercise is to showcase how the proposed approach effectively enhances the system's efficiency in balancing the needs between different types of road users.

Alexandras Ave. holds significant importance as a key corridor within Athens as it serves as a vital link connecting Kifisias Ave. with Patision Ave., major urban corridors that play a crucial role in connecting the northern and western sectors of Athens to the city centre (Figure 2). Spanning a length of 2.7 kilometres, Alexandras Ave. includes 14 signalised intersections, from where more than 8,000 vehicles pass in 1 hour on a typical day, highlighting its criticality. This avenue is a hub for public transportation, with 15 bus lines and 21 bus stops across its length. Notably, Alexandras Avenue features two lanes in each direction, supplemented by an exclusive bus lane in both directions.

Figure 2 - Alexandras Ave. in Athens

Validation Scenarios

The scenarios will be based on typical day traffic patterns, incorporating both transit and car demand to ensure a realistic assessment. Three main road space utilisation approaches will be tested: Dedicated Bus Lanes (DBL), Mixed Traffic Conditions without any prioritisation for buses, and CONDUCTOR’s cooperative traffic management system, which dynamically allocates road space and optimizes traffic signal timings.

The Reference Scenario for this validation will assume demand patterns of a typical day under DBL, representing the Business as Usual (BAU) conditions for Alexandras’ Avenue. This scenario serves as a baseline to assess the effectiveness and improvements brought about by the CONDUCTOR's management system. By comparing the outcomes with those of the Reference Scenario, the exercise aims to highlight the potential benefits in terms of traffic flow, public transportation efficiency, and overall road space utilisation, thereby providing a clear picture of the system's impact on urban mobility.

Validation exercise platform / tool and validation technique

The validation exercise will be conducted within the Aimsun simulation platform, facilitated by API communication via Python to allow for the real-time adjustments needed for dynamic signal control and space allocation strategies. The Key Performance Indicators outlined in

Table 4, will be derived directly from the simulator outputs. To guarantee a fair and consistent comparison between the different scenarios all simulation experiments will be run until all vehicles have completed their trips.

Data collection and analysis

This is a simulation-based exercise, therefore all essential data required for validation will be sourced from the Aimsun Next simulation software, after running multiple simulation experiments using various simulation seeds. The proposed solutions' impact and efficacy will be assessed quantitatively against the predefined KPIs, as described. The outputs will be stored in CSV files exported by the Aimsun Next software.

Participants

The participating partners in this validation exercise are NTUA, OASA and Aimsun. Their role within the exercise is described below.

- NTUA will design the Cooperative Traffic Management System, perform scenario experiments, and analyse the results.
- Aimsun will support NTUA on the integration of the Cooperative Traffic Management System into the Aimsun Next simulation environment.
- OASA, as a stakeholder and the public transport authority of Athens, will provide the telematics of their buses to support the development of realistic transit demand scenarios.

Exercise planning

The planning of this exercise is contained in Table 17.

Table 17 - Planning for Exercise #01 - UC1 Athens

Exercise	Activity	Partner	Months			
			18-21	22-25	26-30	31-35
#01	Refinement of the MARL environment and training of MARL agents	NTUA	■	■		
	Support NTUA on the development of the Cooperative Traffic Management System in Aimsun Next	Aimsun		■	■	
	Execution of simulation experiments	NTUA			■	
	Support NTUA on the execution of the simulation experiments	Aimsun			■	
	Analysis of results and conclusions	NTUA				■

Identified risks and mitigation actions

In conclusion, Table 18 outlines the risks associated with validation exercise #01 of UC1 Athens, detailing their impact level, likelihood, criticality, and the corresponding mitigation measures.

Table 18 - Identified risks for exercise #01 - UC1 Athens

Risk	Impact (1-low, 2-medium, 3-high)	Likelihood (1-low, 2-medium, 3-high)	Criticality (as the product of likelihood and impact)	Mitigation action
Complexity of the MARL training process	2-medium	2-medium	4	Fine-tuning of components' hyperparameters

4.1.2 Validation exercise #02

This validation exercise will describe the **ETA estimation of buses based on the Multimodal Fleet Management System with incident detection and management,** developed by Ridango in WP2, Task 2.2, for validation in UC1 Athens.

The validation exercise will comprise of the following sub-exercises:

- ETA audit
- Incident management module

Validation exercise description

ETA audit sub-exercise description

In this exercise we will evaluate the developed enhanced ETA engine as part of the Fleet Management system; the objective is to compare the ETA calculated by Ridango ETA engine with the existing OASA ETA.

The expectation is that Ridango ETA engine provides more accurate estimations, which in return result in improved passenger experience, enhanced punctuality, and increased ridership.

The basis for ETA calculation and comparison will be either real-time data containing stop arrival predictions or 1-day delay bus position data also including stop arrival predictions; data will be provided by OASA.

Incident management sub-exercise description

In this exercise, we will evaluate the developed Incident management module and its associated sub-modules (configuration tools, APIs, action tools) as part of the Fleet Management system.

The objective of this exercise is to showcase how the incident can be either created via some external system via API or within the Fleet management web-based application (for the exercise purposes the use of user interface and the possibility to “manually” trigger an incident); with the incident being either associated with specific bus(es) or route(s) as well as to also showcase what are all the available action tools for public transport operators.

Validation Scenarios

ETA audit sub-exercise

The scenario will be based on the existing OASA Real-time data or 1-day delay data containing stop predictions.

For this purpose, we developed a virtual logical entity reflecting some of the operations of an actual bus. We can feed this entity with bus data like position, time, speed and trip/route selection and it then calculates its virtual trip status, triggers stop arrivals, stop departures, off-route events, etc.

The ETA calculation will be done for all provided data; however, the emphasis will be on Alexandras Avenue and associated routes and stops.

Incident management sub-exercise

This exercise involves the solution part and will be based mostly on the simulation of Incident Management solution from incident detection, determination of the appropriate response to incident and use of appropriate action tools as response, and dissemination via different channels to post incident reporting.

The idea is that this exercise results in providing general guidance on how the incident management could be implemented within public transport organization and how the data can be disseminated to various 3rd party system as disruption information is one of the most important information to passengers.

Validation exercise platform / tool and validation technique

ETA audit sub-exercise

This exercise will be conducted with Fleet Management System and incorporated ETA engine.

To validate the information also the Fleet Management system – the web-based application will be used to check the ETA calculation, for the ETA accuracy in-built ETA accuracy report will be provided.

Incident management sub-exercise

To conduct this exercise the following components are required:

- Fleet Management System – web-based application with developed Incident management module
- Incident Management REST APIs.

Along with the Incident management module also different visualization options will be utilized (incident trigger notification, map display).

Data collection and analysis

ETA audit sub-exercise

The input for this exercise will be OASA Real time data – GTFS Real time vehicle position and trip updates or 1 day delay data containing bus position information as well as stop arrival predictions.

The outputs will be visualized within the Fleet Management web-based application (ETA calculation, ETA accuracy report) as well as available for export in comma-separated values (.csv) format (ETA accuracy report) and via industry standard interfaces (GTFS Real-time Vehicle position; GTFS Real-time trip updates, SIRI Stop Monitoring (SM)).

Incident Management sub-exercise

The input for this exercise will be occurrence triggered via incident REST API provided by Ridango or manually created via Fleet management web-based application and its Incident module (user interface with manually activated incident option).

Incident management data will be visualized via Fleet Management system; the outputs will be stored in database as well as available for export in .csv format; access to triggered incidents will be also via REST API.

Participants

The participants in the validation exercises are Ridango and OASA.

Exercise planning

The planning of this exercise is contained in Tables 19 and 20.

Table 19 - Planning for exercise #02 sub 01 - UC1 Athens

Exercise	Activity	Partner	Months			
			18-21	22-25	26-30	31-35
#02 Sub 01	Initial input data consolidation for OASA ETA	Ridango	■			
	Initial input data consolidation for Ridango ETA	Ridango	■			

	ETA engine execution and statistics gathering	Ridango				
	OASA ETA data gathering	Ridango				
	ETA audit analysis-reporting and conclusions	Ridango				

Table 20 - Planning for exercise #02 sub 02 - UC1 Athens

Exercise	Activity	Partner	Months			
			18-21	22-25	26-30	31-35
#02 Sub 02	Use case preparation for incident simulation	OASA				
	Execution of incident simulations	Ridango				
	Output evaluation	Ridango				

Identified risks and mitigation actions

The table below reports the identified risks for validation exercise #02 – UC1 Athens.

Table 21 - Identified risks for exercise #02 - UC1 Athens

Risk	Impact (1-low, 2-medium, 3-high)	Likelihood (1-low, 2-medium, 3-high)	Criticality (as the product of likelihood and impact)	Mitigation action
Data availability	3 - high	3-high	9	Obtain historical data for limited time period and limited area (routes and stops)
Components are not ready for validation sub-exercise	3-high	1-low	3	The algorithms are being iteratively developed and tested within various scenarios. Preliminary tests are executed to mitigate the risk

4.1.3 Validation exercise #03

This validation exercise presents the **Vehicle Scheduling Model for Autonomous and Connected Vehicles**, developed by UTwente and NTUA in WP2, Task 2.3, for validation in UC1 Athens. The objective of this component is to dynamically adjust the dispatch times of feeder line trips to minimise passenger waiting times, synchronising the feeder and collector lines' arrival times at the transfer stops. A system-wide optimisation of generalised passenger travel times is proposed, supported by the predictive capabilities of machine learning algorithms. This component facilitates the improvement of multimodal service synchronisation through increased regularity and attractiveness of the public transit system, supporting seamless mobility and reducing passenger transfer times.

Validation exercise description

The operational scope of this validation exercise is described as follows:

To execute this component, a framework consisting of two phases is devised; First a forecasting module, following Machine Learning (ML) workflow principles, is cyclically developed, trained, tested, and fine-tuned to detect, and predict, patterns within public transport service performance. The forecast would serve as dynamic input for the second phase of the component, which adjusts control measures (such as dispatching time, bus holding, etc…) within a real-time context, supporting the optimisation of passenger travel time and an enhanced synchronisation between feeder and collector lines. Depending on the control measures evaluated for, (e.g., dispatching time, speed control, etc…) and their relation to service indicators (e.g., number of missed transfers), simulation is used to evaluate the framework's performance, assessed within the scope of the key performance areas and indicators outlined within Table 4.

Validation Scenarios

The reference and solution scenario of this validation exercise is presented below:

This model will be validated on a testbed based on the multimodal public transportation network of Athens, consisting of both its subnetwork's collector lines (Light Rail), and the feeder lines of the bus subnetwork, operated by the public transport authority stakeholder OASA. In developing the forecasting module, its' cyclical validation and fine-tuning workflow will be assessed against the historical data set aside as a baseline test-dataset. The real-time control of the framework will be evaluated in terms of control measures and their interrelation with service indicators (e.g., number of missed transfers), such that for the case of dispatching time, a baseline scenario may potentially be determined based on real-world observations, allowing for the dynamic exercise to be assessed in comparison to its pre-existing static counterpart. Different control measures may be carried out within a simulation of the Athens' testbed. The reference scenario would thus be deterministically generated based on the scheduling and transfer synchronization patterns of a typical day. By comparing the two scenario outcomes, the regularity of public transport will be monitored, and analysed for its effect on reducing passenger transfer times.

Validation exercise platform / tool and validation technique

The Vehicle Scheduling Model for Autonomous and Connected Vehicles validation exercise will be simulated within a Python Integrated Development Environment (IDE). It will simulate and support the dynamic adjustment of its real-time control. The Key Performance Indicators outlined in

Table 4, will be derived directly from the optimisation and simulation outputs.

Data collection and analysis

As the validation exercise is optimisation- and simulation-based, the input and output data will be predominantly quantitative. As a result of the simulation, the KPIs from Table 6 will be related to and assessed from its output. The validation of the exercise collects data such as schedules, departure times, passenger transfer waiting times, etc., and the output may be collected as a .csv file. These outputs will be saved in .csv format files.

Participants

The participating partners in this validation exercise are NTUA and OASA. Their role within the exercise is described below:

- NTUA will generate the initial input data for both the optimisation- and simulation-based frameworks of the validation exercise, perform scenario experiments, and analyse the results.
- OASA, as a stakeholder and the public transport authority of Athens, will provide the telematics of their buses to support the validation of the Vehicle Scheduling Model for Autonomous and Connected Vehicles.

Exercise planning

The planning of this exercise is contained in Table 22.

Table 22 - Planning for exercise #03 - UC1 Athens

Exercise	Activity	Partner	Months			
			20-23	24-27	28-31	32-35
#03	Initial input data generation model	NTUA				
	Execute initial experiments for the baseline scenarios of the exercises	NTUA				
	Execution of simulation experiments	NTUA				
	KPI computation	All				
	Analysis of results and conclusions	NTUA				

Identified risks and mitigation actions

Finally, Table 23 presents the risks for validation exercise #03, including their impact level, likelihood, criticality, and corresponding mitigation actions.

Table 23 - Identified risks for exercise #03 - UC1 Athens

Risk	Impact (1-low, 2-medium, 3-high)	Likelihood (1-low, 2-medium, 3-high)	Criticality (as the product of likelihood and impact)	Mitigation action
Components are not ready for the validation exercise	3 - high	2 - medium	6	The algorithms are being iteratively developed and tested within various scenarios. Preliminary tests are executed to mitigate the risk

4.2 Use Case 1 – Almelo

Urban logistics operations are influenced by delays at traffic lights. Every time a truck comes to a standstill due to a red signal and must accelerate after the light has turned green additional fuel is consumed compared to an uninterrupted pass, resulting in major costs. For example, accumulated local delays may be manifested in route plans and impact efficiency and reliability of operations. The stops of trucks not only impact logistics services but also have a wider impact, e.g., on network-wide traffic conditions due to a decreased capacity and on GHG emissions and safety. The city of Almelo, the Netherlands, has recently installed a series of intelligent traffic light controllers (iTLCs), able to communicate with vehicles and road users in an effective, safe and platform-independent way. This brings information from the traffic controllers to the road users and vice versa. Considering the impacts of stopping trucks, and with a substantial share of the traffic volumes in Almelo related to freight transport, the goal of the UC1 Almelo pilot is to reduce the number stops for trucks along a logistics corridor connecting major roads with logistics hubs in the city. The use case focuses on validating the effectiveness of traffic management strategies developed as part of CONDUCTOR, utilizing communication between vehicles and intelligent traffic controllers, with particular attention for balancing supply and demand, and governance issues related to the prioritization of specific vehicle types. Specifically, various CCAM functionalities will be applied to minimize the number of stops: (i) conditional priority for freight traffic at iTLCs (freight signal priority), (ii) real-time communication of current and near-future traffic signals to facilitate smooth progression, and (iii) the coordination of signals facilitating an uninterrupted progression when traveling along the arterial (green wave). Through tests in both a real-world and simulation environment, the goal of UC1 Almelo is to determine the conditions under which priority for trucks can be granted. This relates to a multi-actor, multi-objective problem in the sense that priority may only be granted if it does not significantly worsen the (near-)future traffic situation in the entire network. Hence, a governance model balancing different criteria is required.

The validation exercises related to UC1 Almelo are as follows:

1. *Validation exercise #01:* Quantification of impacts of conditional freight signal priority and communication of signal status information;
2. *Validation exercise #02:* Quantification of CCAM functionalities (freight signal priority, communication of signal status and green waves) for freight traffic under fluctuating traffic conditions and varying market penetration rates.

These two validation exercises are further described below.

4.2.1 Validation exercise #01

Recently, the signalized intersections on the ring roads of Almelo have been equipped with intelligent traffic control systems, enabling communication from and to road users. In this use case, a pilot project will be conducted to reduce the number of stops of freight vehicles at these traffic lights through novel traffic management strategies, expected to bring considerable benefits. In the context of this use case, the aim is to provide an uninterrupted pass at the intelligent controllers in Almelo. Therefore, during the pilot, truck drivers will be equipped with a smartphone or on-board computer, on which an application will be installed. Through this application, communication between traffic controllers and truck drivers becomes possible. Specifically, truck drivers receive information about the near-future traffic signal allowing them to adjust their speed accordingly and can request priority when approaching the intersection. Priority requests are granted or rejected based on the controller policy and the traffic situation at hand. For example, requests can be rejected in case emergency vehicles arrive at the intersection. The goal of the pilot is to define the conditions under which priority *can* be granted, specifically focusing on governance issues related to prioritization of specific vehicle types at a potential cost for other road users. The execution and impact assessment of this real-world pilot test with the relevant stakeholders enables local governments and authorities to balance priority issues in their traffic management policies.

Validation exercise description

The validation exercise will be executed in two phases. The first phase relates to an initial integration scenario. As part of this scenario, communication from iTLCs to truck drivers and vice versa will be facilitated using an application for the smartphone or the on-board device. Through this application, truck drivers automatically send priority requests once approaching an iTLC on the ring road of Almelo. Such a priority request also includes information on the (geo-)location and speed, so that an estimate can be made for which traffic light or direction priority is requested. Based on the controller policy determined by the responsible authority, priority requests are granted or rejected, and the truck driver will receive a notification. Where possible, drivers will receive real-time time-to-green and time-to-red information through the application. Based on evaluations of the first phase with the involved stakeholders, improvements will be made to the system including the policy for granting or rejecting priority requests. The improved system will be evaluated in a similar manner as the first phase during a second phase. Impact assessment occurs by comparing the integration scenarios with the baseline or reference scenarios, using key performance areas and indicators as described in Section 3.2.2. Particular focus will be put on identifying trade-offs between the different key performance areas, performance indicators, and user groups.

Validation Scenarios

Each phase of the pilot lasts various weeks. For each phase, a reference scenario or baseline scenario or situation will be established. However, such a single baseline situation is difficult to define due to longer-term variations in traffic volumes, e.g., seasonal variations. Therefore, the freight signal priority component of the control system will be switched on and off for a limited time period within each phase of the pilot. That is, during each phase a baseline situation will be established in a dynamic fashion allowing for an accurate impact assessment.

Validation exercise platform / tool and validation technique

The validation exercise will be performed in real world, as part of the UC1 Almelo pilot. Communication between the traffic light control systems and trucks is facilitated by an application and cloud service provider.

Data collection and analysis

During the course of the exercise, data will be collected mainly using roadside and moving sensor data. Data collected using roadside sensors include data from inductive loop detectors installed near traffic signals, detecting both motorized vehicles and bicycles. Various induction loops are present near each signalized intersection: a stop loop near the stop line to detect the presence of waiting vehicles, a long loop detecting queues or approaching vehicles, and a distant loop further upstream detecting approaching vehicles. These data are collected in real time with a 10Hz frequency, stored in log files, and can be accessed through the municipal data access point. These log files additionally include data from traffic signals such as “event” data when the signal turned green, amber, red, but also information about green (through either induction loop or push-button detections) and priority requests (emergency services, public transit, etc.). Anonymized communication messages (e.g., SPAT and CAM messages) between connected vehicles and infrastructure (iTLCs) are collected and stored in log files in the national urban data access platform. Moving sensor data include geolocation, planned route and speed information of each truck part of the validation exercise. Additional data used include weather information on precipitation, temperature, etc. (publicly available), as well information about public works, road maintenance, etc. Additionally, data will be collected using surveys, workshops, and interviews with the identified stakeholders on expectations but also to assess the effects of the exercise on experiences and perceptions.

Regarding the data analysis, impacts will be assessed using a system, a user (journey), and logistics perspective. The effects on logistics operations include a comparison of travel times, delays and estimated fuel consumption largely based on moving sensor data from trucks and V2I communication messages. This analysis also entails an impact assessment on the operations of non-participating logistics companies. Truck drivers will be interviewed about their experiences and the perceived effects. The spatio-temporal impacts on traffic are assessed by comparing the distribution delays, travel times, etc. for “similar” traffic situations with and without priority requests. This analysis is not limited to individual intersections and cycles since effects may propagate in time and space.

Participants

CONDUCTOR partners participating in this validation exercise are Gemeente Almelo and University of Twente. Gemeente Almelo is the pilot project coordinator, and responsible for data collection. University of Twente is conducting the impact assessment.

Exercise planning

The activities part of validation exercise #01 are presented in Table 24.

Table 24 - Planning for exercise #01 - UC1 Almelo

Exercise	Activity	Partner	Months									
			18	19	20	21	22	23	24	25	26	27
#01	Preparation: test technical functionalities, data collection	UT / Almelo	■									
	Kick-off, first phase pilot	UT / Almelo		■	■							
	Impact assessment first phase	UT / Almelo		■	■	■	■					
	Preparation phase 2: technical tests, optimized scenario integration	UT/ Almelo					■	■				

	Second phase pilot	UT / Almelo										
	Impact assessment second phase	UT / Almelo										
	Evaluation, reporting	UT / Almelo										

Identified risks and mitigation actions

Table 25 presents the risks for validation exercise #01.

Table 25 - Identified risks for exercise #01 - UC1 Almelo

Risk	Impact (1-low, 2-medium, 3-high)	Likelihood (1-low, 2-medium, 3-high)	Criticality (as the product of likelihood and impact)	Mitigation action
Definition reference scenario	3-high	1-low	3	The baseline or reference scenario defined may show unusual patterns which may complicate impact assessment. In the plan, scheduled events are taken into account and multiple reference scenarios are defined

4.2.2 Validation exercise #02

Vehicle-actuated controls are widely applied in the Netherlands, where signal timings depend on the presence of vehicles, cyclists, and pedestrians detected through induction loops, cameras, radar or push buttons. From a logistics operations perspective, control systems can be improved by allowing for an uninterrupted progression of platoons or convoys of trucks along a series of signalized intersection, significantly reducing fuel consumption and thereby cost, improving operation efficiency, and contributing to climate and environment objectives. By implementing a ‘green wave’ combined with green light optimized speed advice (GLOSA), the number of stops can be minimized. However, coordination between intersections and communication between infrastructure and vehicles is required. Through simulation-based experiments, we assess the potential effects of platoon or convoy-based signal coordination combined with GLOSA at the Almelo ring road under various scenarios.

Validation exercise description

The validation exercise involves a multi-criteria evaluation of freight platoon-based signal coordination at urban arterials under different scenarios. The exercise particularly focuses on the validation of the designed coordinated freight signal priority policies and speed advice algorithms, and the potential scalability of results under varying market penetration rates regarding connected trucks and the exercise is therefore executed in a simulation environment.

Validation Scenarios

In this validation exercise, we particularly focus on morning peak traffic (between 07:00 and 10:00 AM) in the Almelo network and compare the following scenarios: (i) vehicle-actuated control system without coordination (reference or baseline scenario), (ii) control with freight signal priority, and (iii) coordinated control with freight convoy signal priority and speed advice. Scenario (ii) relates to validation exercise #01, but in a simulation environment we maintain a degree of flexibility, for example regarding a refinement of the priority scheme.

Validation exercise platform / tool and validation technique

The validation will be accomplished in Aimsun Next with Python API concerning the reference scenario (existing situation) and platoon-based coordinated signal controls as explained in the previous section. The API connection facilitates online data exchange between the simulation environment and signal optimization modules, as well as managing signal timings and vehicle speed for prioritization purposes.

Data collection and analysis

During the simulation process, various datasets will be collected from loop detectors, tracked vehicles, and signal controls. Similar to exercise #01, various loop detectors (e.g., stop loop, long loop, distant loop) are installed at each intersection. Through an API connection, we extract the detector data per simulation step (10 Hz), including instant detection, vehicle volume, traffic composition, occupied time, and information of the equipped vehicles. We also track some heavy-duty vehicles when they enter the network until they exit. Detailed information of these of vehicles (e.g., speed, position, acceleration/deceleration, stops, delays) will be used as input for GLOSA and granting conditional signal priority. Since we use vehicle-actuation signal control system, data of the signal settings will be exchanged in real-time with the external C-TSC module to continuously determine the optimal signal timings and coordinate a series of intersections.

Additional data such as number of stops, delays and emissions will be collected at the end simulation period. Such datasets will be used to evaluate the impacts of signal coordination and conditional freight signal priority on various road users under different scenarios. Similar to exercise #1, we will compare the number of stops and delays of equipped trucks throughout the corridor as a result of GLOSA and signal prioritization and how this affected the rest of the traffic. We differentiate among road user groups to assess the potential (negative) impacts of freight signal prioritization in terms of GHG emissions and air quality per user group.

Participants

CONDUCTOR partners participating in this validation exercise are Gemeente Almelo, Aimsun and University of Twente. Gemeente Almelo performs data collection, Aimsun and University of Twente are involved in setting-up the simulation environment and University of Twente performs the impact assessment.

Exercise planning

The planning of this exercise is contained in Table 26.

Table 26 - Planning for exercise #02 - UC1 Almelo

Exercise	Activity	Partner	Months									
			20	21	22	23	24	25	26	27	28	29
#02	Definition study area, scope and scenarios	UT, Almelo	■	■								
	Integration components and calibration simulation	UT, Almelo, Aimsun		■	■	■	■					
	Execution of traffic simulations	UT			■	■	■	■	■			
	KPI computations	UT				■	■	■	■	■		
	Analysis of results	UT / Almelo								■	■	
	Conclusions, reporting	UT/ Almelo								■	■	■

Identified risks and mitigation actions

The identified risks for exercise #02 are contained in Table 27.

Table 27 - Identified risks for exercise #02 - UC1 Almelo

Risk	Impact (1-low, 2-medium, 3-high)	Likelihood (1-low, 2-medium, 3-high)	Criticality (as the product of likelihood and impact)	Mitigation action
Components adjustments required for integration	3-high	1-low	3	The components have been developed in earlier stages of the project but may need adjustments for the validation exercise. Preliminary tests are executed to mitigate impacts

4.3 Use Case 1 – Madrid

UC1 Madrid focuses on the management of events/ incidents for recovery of optimal transport network operations. The testing and validation of UC1 Madrid will be conducted in a simulation context, necessary to test various scenarios regarding CCAM market penetration. Data from both virtual roadside sensors, as well as individual vehicles' trajectory data, will be used to monitor and evaluate progress regarding the formulated objectives, using the technical, business, and environmental social KPIs outlined in Table 8. Network characteristics and demand levels required as input by the simulation software need to be defined.

The simulation scenarios to be performed within UC1 are summarized below:

1. **Baseline scenarios**: Two baseline scenarios will be designed involving planned and unplanned events in the network of Madrid. The results will serve as the baseline to assess the effectiveness of different response plans to be deployed during network disturbances.
2. **Planned event scenarios**: These scenarios will involve a planned event in the network where different congestion mitigation strategies will be tested. The demand will consist of mixed traffic involving Connected and Automated Vehicles (CAVs) as well as conventional vehicles. Connectivity will be assumed between vehicles and the infrastructure, allowing the assumed connected vehicles to receive route guidance. The network-wide impacts (including both the affected area and surrounding network) will be evaluated at different penetration rates of connected vehicles. The simulation results could be used to support decision-making.
3. **Unplanned event scenarios**: These scenarios will involve an unplanned (sudden) event in the network where different congestion mitigation strategies will be tested similarly to the planned event scenario mentioned above.

The validation exercises are defined based on comparisons between these scenarios as follows:

1. Validation exercise #01 identifies and quantifies the impacts of planned and unplanned events in the network by analysing adequate measurements to be obtained from the simulation.
2. Validation exercise #02 compares the baseline scenario with the planned event scenarios after the activation of specific response plans.
3. Validation exercise #03 compares the baseline scenario with the unplanned event scenarios after the activation of specific response plans.

The three validation exercises will be simulated using the transport simulator Aimsun Next, for the Madrid city network (Figure 3).

Figure 3 - Madrid city network in Aimsun Next

4.3.1 Validation exercise #01

Validation exercise description

Validation exercise #01 will perform simulation analyses to investigate the impacts of prespecified planned and unplanned events in specific areas of the network (M-30 ring road) and time periods (e.g., morning and evening peaks). The impacts will be identified and quantified both for the impacted area (ring road) as well as for the surrounding network to capture potential impacts from the redistribution of traffic to secondary roads due to the events. In these scenarios no optimal transport operations will be assumed, hence no connectivity between vehicles and the infrastructure. The impacts on the network performance as well as the time needed for the network to recover back to normal conditions will be analysed.

Validation Scenarios

This exercise involves only a reference scenario, where the different types of events (planned and unplanned) will be replicated in simulation to obtain the impacts that will be used as the baseline in the following exercises to assess the effectiveness of the mitigation strategies to be deployed.

Validation exercise platform / tool and validation technique

This exercise will be performed in a simulation environment. In particular, the simulation software Aimsun Next will be used to replicate the planned and unplanned events. The results will be used as the baseline to compare with the results to be obtained in the following exercises.

Data collection and analysis

This is mainly a simulation-based validation exercise, hence, most of the input and output data will be quantitative. In particular, the Aimsun Next simulation software will be used to perform this exercise. With respect to the approach for assessing and validating the scenarios to be carried out, different statistical measurements will be obtained from the simulation. The impact and effectiveness of the proposed solutions will be evaluated qualitatively in relation to the predefined KPIs. Statistical tests can be also used to indicate the significance level in terms of KPI improvements, compared to the corresponding measurements of the baseline scenario.

The outputs will be stored in a Database exported by the Aimsun Next software as well as in other formats such as CSV files. Moreover, the animated outputs will be visualised within the simulation environment by displaying and drawing different simulation outputs at different levels (vehicle, road sections, paths, etc.) that will assist the interpretation and dissemination of the results.

Participants

The participants of this exercise will be Aimsun, Deusto and Nommon with the specific roles:

- Aimsun will perform the traffic simulations for each scenario to retrieve the needed statistics and KPIs.
- Deusto will apply the optimization algorithms for optimal rescheduling and other mitigation strategies involving CAVs for each identified scenario.
- Nommon will generate the penetration rates for the demand involving CAVs that will be used as input to the simulation.

Exercise planning

The following activities will be performed within exercise #02:

- A01: Definition of study area.
- A02: Definition and selection of planned/unplanned events.
- A03: Execution of traffic simulations for the baseline scenario.
- A05: KPI computation.
- A06: Analysis of results.

The planning of this exercise is contained in Table 28.

Table 28 - Planning for exercise #01 – UC1 Madrid

Exercise	Activity	Partner	Months					
			19	20	21	22	23	24
#01	01	All	■					
	02	Aimsun, Deusto	■	■				
	03	Aimsun		■				
	04	Aimsun			■	■	■	■
	05	All					■	■
	06	Aimsun, Deusto					■	■

Identified risks and mitigation actions

Table 29 reports the main identified risks for validation exercise #01.

Table 29 - Identified risks for exercise #01 - UC1 Madrid

Risk	Impact (1-low, 2-medium, 3-high)	Likelihood (1-low, 2-medium, 3-high)	Criticality (as the product of likelihood and impact)	Mitigation action
The developed simulation model (simplified mesoscopic) is not reflecting the expected traffic conditions	2-high	2-medium	4	Preliminary tests will be performed to assess the accuracy of the model and make improvements if needed.

4.3.2 Validation exercise #02

Validation exercise description

Validation exercise #02 will compare the baseline scenario with the planned event scenarios after the activation of specific response plans. Different response plans will be defined, implemented and assessed, including identification of routes for evacuation, prioritization of emergency vehicles, control of access on the ring highway, lanes management, alternative routes for avoiding specific road stretches in the M-30. The final experimental design with the exact scenarios to be tested will be defined in coordination with Madrid Calle 30.

Validation Scenarios

The reference scenario refers to the scenario involving a planned event (the type of event is to be defined) that will be replicated in simulation in Validation Exercise #01. The outputs of the reference scenario will be used as the baseline in this exercise to assess the effectiveness of the mitigation strategies to be deployed.

The solution scenario will include different traffic management strategies to mitigate the impacts due to the planned event. Different penetration rates for connected vehicles that will receive traffic information, guidance, etc., will be assumed and the scenarios will be simulated and compared against the reference scenario. The different strategies will involve rescheduling connected vehicles, involving departure time calculations and rerouting under different conditions (events).

Validation exercise platform / tool and validation technique

To conduct this exercise, the following components are required:

- CAV demand estimation component: the estimated demand of the connected vehicles will be generated using the *Data Fusion for Travel Demand Estimation and Characterization* component, which is being developed by Nommon.
- Optimal demand-supply balancing strategies are applied to obtain the optimal routes for each scenario. These optimal routes will be generated through the *Hierarchical traffic scheduling and control of CAVs routes optimization* component, which is being developed by Deusto.
- Simulation platform: The simulation environment (Aimsun Next) will be used to replicate the planned events and the traffic management strategies and actions to be derived and evaluated.

Data collection and analysis

This is mainly a simulation-based validation exercise, hence, most of the input and output data will be quantitative. In particular, the Aimsun Next simulation software will be used to perform this exercise. With respect to the approach for assessing and validating the scenarios to be carried out, different statistical measurements will be obtained from the simulation. The impact and effectiveness of the proposed solutions will be evaluated qualitatively in relation to the predefined KPIs. Statistical tests can be also used to indicate the significance level in terms of KPI improvements, compared to the corresponding measurements of the baseline scenario.

The outputs will be stored in a Database exported by the Aimsun Next software as well as in other formats such as CSV files. Moreover, the animated outputs will be visualised within the simulation environment by displaying and drawing different simulation outputs at different levels (vehicle, road sections, paths, etc) that will assist the interpretation and dissemination of the results.

Participants

The participants of this exercise will be Aimsun, Deusto and Nommon with the specific roles:

- Aimsun will perform the traffic simulations for each scenario to retrieve the needed statistics and KPIs.

- Deusto will apply the optimization algorithms for optimal rescheduling of CAVs for each identified scenario.
- Nommon will generate the penetration rates for the demand involving CAVs that will be used as input to the simulation.

Exercise planning

The following activities will be performed within exercise #02:

- A01: Demand data generation for CAVs.
- A02: Generation and testing of optimized CAV routing strategies for **planned** events and integration with simulation.
- A03: Generation and testing of other optimized mitigation strategies for **planned** events (TBD).
- A04: Traffic simulation with optimized strategies for planned events and different CAV penetration rates.
- A05: KPI computation.
- A06: Analysis of results and conclusions.

The planning of this exercise is contained in Table 30.

Table 30 - Planning for exercise #02 - UC1 Madrid

Exercise	Activity	Partner	Months									
			20	21	22	23	24	25	26	27	28	29
#02	01	Nommon	■	■	■							
	02	Deusto	■	■	■	■	■					
	03	Aimsun, Deusto	■	■	■	■	■					
	04	Deusto, Aimsun				■	■	■	■	■		
	05	All								■	■	
	06	Aimsun, Deusto									■	■

Identified risks and mitigation actions

Table 31 reports the main identified risks for validation exercise #02.

Table 31 - Identified risks for exercise #02 - UC1 Madrid

Risk	Impact (1-low, 2-medium, 3-high)	Likelihood (1-low, 2-medium, 3-high)	Criticality (as the product of likelihood and impact)	Mitigation action
The developed simulation model (simplified mesoscopic) is not reflecting the expected traffic conditions	2-high	2-medium	4	Preliminary tests will be performed to assess the accuracy of the model and make improvements if needed.

4.3.3 Validation exercise #03

This exercise has the same specification as Validation exercise #03 with the main difference being the type of events that will be analysed. In particular, unplanned events will be studied in exercise #03, while exercise #02 tackles planned events.

Exercise planning

The following activities will be performed within exercise #02:

- A01: Demand data generation for CAVs.
- A02: Generation and testing of optimized CAV routing strategies for **unplanned** events and integration with simulation.
- A03: Generation and testing of other optimized mitigation strategies for **unplanned** events (TBD).
- A04: Traffic simulation with optimized strategies for planned events and different CAV penetration rates.
- A05: KPI computation.
- A06: Analysis of results and conclusions.

The planning of this exercise is contained in Table 32.

Table 32 - Planning for exercise #03 - UC1 Madrid

Exercise	Activity	Partner	Months									
			20	21	22	23	24	25	26	27	28	29
#03	01	Nommon	■	■	■							
	02	Deusto	■	■	■	■	■					
	03	Aimsun, Deusto	■	■	■	■	■					
	04	Deusto, Aimsun				■	■	■	■	■		
	05	All								■	■	
	06	Aimsun, Deusto									■	■

4.4 Use Case 2

Since Slovenia has poor airport connectivity, many travellers use airports in neighbouring countries to reach their destination directly. Some of the most popular airports for Slovenian travellers are Trieste (Italy), Zagreb (Croatia) and Vienna (Austria) as shown in Figure 4.

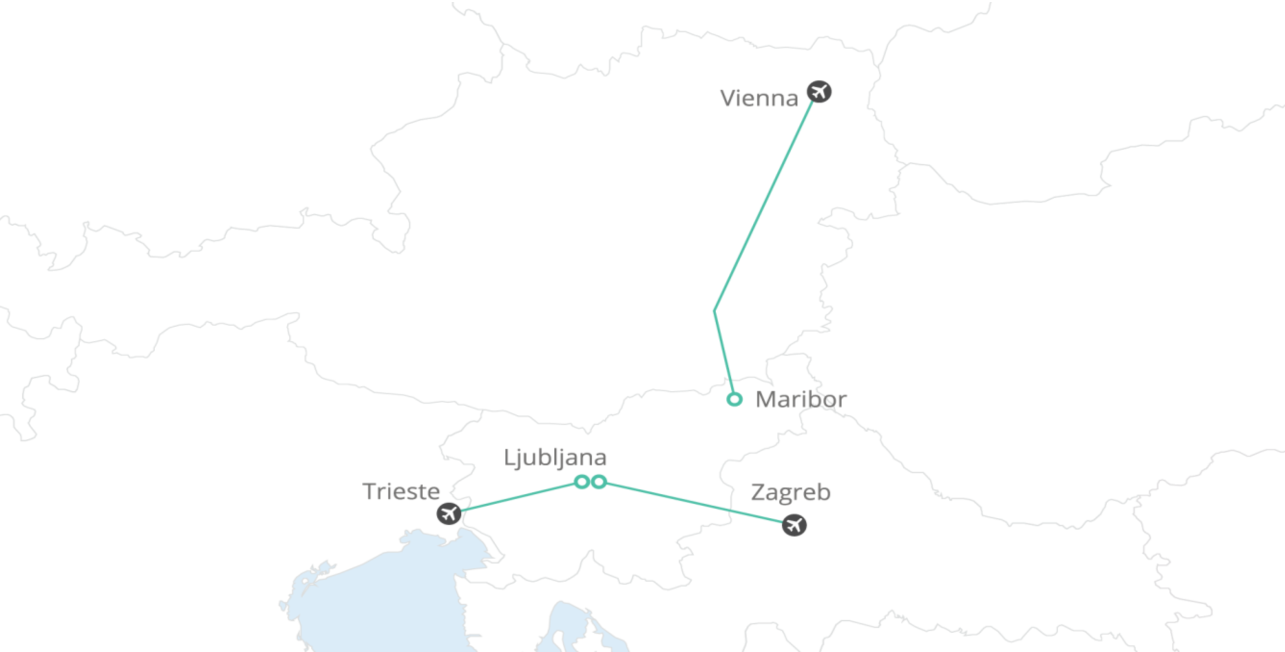

Figure 4 - The three validation routes for UC2

To reach these destinations travellers again have limited options. Public transport to these cross-border locations is slow or non-existent. To connect travellers to these airports, GoOpti offers a DRT service.

In the scope of CONDUCTOR, GoOpti identified an opportunity to improve their service and test new technologies. UC2 will upgrade the current GoOpti's service with new functionalities that will enhance the customer experience as well as reduce the costs of operations. These new functionalities are:

- DRP
- Routing optimisation
- Continuous planning with smart triggers based on events
- Demand prediction (DP)

With this new functionalities GoOpti aims to improve customer experience, reduce costs, reduce CO2 and NOx emissions per traveller, improve work conditions of drivers and planners, enhancing the overall quality of the services.

For the validation of the UC2 we will be testing the newly added functionalities in real-time as well as virtual testing of more experimental functionalities which will be operating with real-time data. The forementioned routes were chosen for easier evaluation as these three routes have similar volume of orders.

For purposes of validation three exercises are envisioned:

1. Validation exercise #01: Validation of DRP and Routing optimisation

2. Validation exercise #02: Validation of Continuous planning with smart triggers based on events
3. Validation exercise #03: Validation of DP model

4.4.1 Validation exercise #01

Validation exercise description

In this first exercise we will be testing the upgraded DRP. The new platform will enable us to run old and new version of components on the same system thus providing us with good baseline for comparing the components. It will be also the most extensive as the platform must be thoroughly tested to ensure the expected availability and reliability of the system.

Also, we will be testing the integration of the Route optimisation. The Routing optimisation must cover a plethora of known and unknown edge case scenarios, which will be uncovered and addressed during testing.

Validation Scenarios

The first task of the exercise will be validating the reliability, availability and scalability of the DRP. The platform will be tested and verified directly in production environment. For this we envisioned a couple validation scenarios:

- Stress test of the platform's infrastructure
- Scaling tests of the platform

The second task of the exercise is to evaluate the routes and plans of the Routing optimisation and the integration of the Routing optimisation component to DRP. The validation will be performed by comparing old planning distances and travel time with the new solution on the following routes:

- Ljubljana – Trieste Airport
- Ljubljana – Zagreb airport
- Maribor – Vienna airport

Validation exercise platform / tool and validation technique

The exercise will be performed on the following components:

- Demand Responsive Transport Platform.
- Routing optimisation: it will be integrated to the DRP It will be validated with optimising route plans which will be compared to the current, unoptimised plans. With time, the new solution will be moved to the production environment.

Data collection and analysis

For validating the DRP the results will be mostly qualitative. The data will be collected through the system logs, where the performance and downtimes of the platform will be analysed.

For validating the Routing optimisation functionality, the distances and travel time of plans will be collected and compared with the baseline plans.

Participants

The only participant in this validation exercise is GoOpti, as the components in validation are vital for their operation and thus must be validated by GoOpti's System Administrators who will evaluate the performance of DRP as well as GoOpti's Planners who will evaluate the optimisation of routes.

Exercise planning

Activities planned:

- A1: DRP integration.
- A2: DRP validation.
- A3: Testing route optimization performance.

Table 33 - Exercise #01 plan for UC2

Exercise	Activity	Partner	Months						
			19-20	21-22	23-24	25-26	27-28	29-30	31-32
#01	A1	GoOpti							
	A2	GoOpti							
	A3	GoOpti							

Identified risks and mitigation actions

The risks associated to validation exercise #01 are listed in the Table 34 below.

Table 34 - Identified risks for exercise #01 - UC2

Risk	Impact (1-low, 2-medium, 3-high)	Likelihood (1-low, 2-medium, 3-high)	Criticality (as the product of likelihood and impact)	Mitigation action

Not all edge cases are covered in Routing optimisation	3-high	3-high	9	An agile Continuous Integration & Development pipeline is set up which enables quick adjustments and testing of adjustments made.

4.4.2 Validation exercise #02

Validation exercise description

The goal of this exercise is to validate an event-based Continuous planning (CP) with smart triggers, which would enable just-in-time bookings, perform plan corrections based on traffic events in real-time, and calculate the number of shuttles on the road and in the model for bookings of GoOpti's service. This would allow for the creation of a more optimal fleet schedule. The exercise will be performed using real-life data in a virtual environment that will run parallel to GoOpti's production environment.

Validation Scenarios

Validation will be done in two scenarios.

The first scenario will focus on CP based on the booking order data and booking order events to enable just-in-time services for bookings.

The second scenario will focus on monitoring unpredicted traffic events for real-time re-optimisation. The routes selected for the UC2 will be divided into several sections with few alternatives for each section. Before reaching each section, a traffic conditions will be checked, and in case of a severe event, the vehicle will be rerouted to the alternative section.

For both scenarios, the CP will be compared to the regular GoOpti plan, which will be used as a reference.

Validation exercise platform / tool and validation technique

The exercise will be performed on the following components:

- Demand Responsive Transport Platform, which will provide the needed data for validation of continuous planning output.
- Continuous planning: The continuous planning service will create plans and forward it to the DRP.
- Traffic event trigger: A service which will be triggering a traffic event for the selected section.
- Traffic event risk factor: A service which will quantify the severity of the risk.

Data collection and analysis

CP will output potential plans for GoOpti's DRT services to the virtual environment using real data. They will be compared with the regular plans to analyse these potential plans. We expect that the following data should be compared:

- Number of passengers per vehicle.
- Time spent on passenger delivery.

Participants

The exercise's participants are GoOpti, JSI, the University of Twente, and Netcompany / Intrasoft. Their roles within the exercise are described below.

- JSI will develop a Continuous planning service that will be integrated into the DRP platform. JSI will integrate the traffic event trigger and risk factor into the Continuous planning. JSI will also perform the statistical analysis of the continuous planning results.
- GoOpti will provide relevant data for Continuous planning. GoOpti will use the Continuous planning outputs in a virtual environment.
- The University of Twente will develop a Traffic event trigger.
- Netcompany / Intrasoft will develop a Traffic event risk factor.

Exercise planning

Activities planned:

- A1: CP development.
- A2: CP integration with DRP.
- A3: CP virtual validation with real data.
- A4: Traffic event risk factor development.
- A5: Traffic event risk factor integration to CP and validation.
- A6: Traffic event triggers development.
- A7: Traffic event triggers integration to CP and validation.

Table 35 - Exercise #02 plan for UC2

Exercise	Activity	Partner	Months						
			19-20	21-22	23-24	25-26	27-28	29-30	31-32
#02	A1	JSI							
	A2	GoOpti							

	A3	GoOpti + JSI							
	A4	INTRA							
	A5	INTRA + JSI							
	A6	UT							
	A7	UT + JSI							

Identified risks and mitigation actions

The risks associated to validation exercise #02 are listed in the Table 36 below.

Table 36 - Identified risks for exercise #02 - UC2

Risk	Impact (1-low, 2-medium, 3-high)	Likelihood (1-low, 2-medium, 3-high)	Criticality (as the product of likelihood and impact)	Mitigation action
Components are not ready for integration	3-high	2-low	6	The validation exercise is designed in a way that allows the iterative validation.
Incomplete traffic data for neighbouring countries (Croatia, Italy, Austria)	3-high	1-low	3	Find alternative data sources. Focus route planning on the sections located in Slovenia for which we have complete data.
Unexpected traffic road closure used in planning	1-low	1-low	1	Find alternative roads

4.4.3 Validation exercise #03

This exercise will focus on validating the DP model, which will be trained on GoOpti's booking order and flight data. It will output the predictions for future time windows for different locations. The DP service will be integrated into DRP through a Continuous planning service.

Validation exercise description

The main goal of this exercise is to create an accurate prediction model for GoOpti's service bookings. This would allow for a more optimal fleet schedule. The exercise will be performed using real-life data in a virtual environment that will run parallell to the production environment.

Validation Scenarios

The scenario's reference data will be the GoOpti's booking orders data. The DP service will output booking predictions for future time windows for different locations. After the actual booking order number is known, the accuracy of the predictions will be calculated.

Validation exercise platform / tool and validation technique

The DP service will be implemented in the Continuous planning service and from there in the DRP.

The exercise will be performed on the following components:

- Demand Responsive Transport Platform, which will provide the needed data and collect the DP output data for evaluation of predictions for planning data.
- Continuous planning: The continuous planning service will use the DP output data and use it to create plans and also forward it to DRP.
- DP: it will be integrated into the DRP through CP. It will be validated by comparing the generated route plans with the current old plans.

Data collection and analysis

For the experiment validation the output of DP and actual order data will be collected. Statistical comparison of the demand and actual orders will be performed. Also, for on the continuous planning we will compare the predicted number of vehicles on the road for certain time window and the actual number of vehicles.

Participants

The participants for the exercise in question are GoOpti and JSI. Their roles within the exercise are described below.

- JSI: will develop a model for DP, integrate it to the Continuous planning service and from there expose the DP to the DRP platform. JSI will also perform the statistical analysis of the model and results.
- GoOpti: will provide relevant data for the DP model. It will also integrate the DP to the DRP platform. GoOpti will use the DP outputs in a virtual environment.

Exercise planning

Activities planned:

- A1: DP development.
- A2: DP integration to CP and virtual validation with real data.

Table 37 - Exercise #03 plan for UC2

Exercise	Activity	Partner	Months						
			19-20	21-22	23-24	25-26	27-28	29-30	31-32
#03	A1	JSI							
	A2	GoOpti + JSI							

Identified risks and mitigation actions

The risks associated to validation exercise #01 are listed in the Table 38 below.

Table 38 - Identified risks for exercise #03 - UC2

Risk	Impact (1-low, 2-medium, 3-high)	Likelihood (1-low, 2-medium, 3-high)	Criticality (as the product of likelihood and impact)	Mitigation action
Models for validation exercise are not performing as expected	2 - medium	3-high	6	Multiple different models are being developed and tested.
Incomplete data for model training	1-medium	2-medium	2	Usage of alternative data sources which are more complete.

4.5 Use Case 3

UC3 aims at developing coordination and integration strategies for urban last mile delivery of parcels and DRT-CCAM services, leveraging the excess capacity of DRT-CCAM vehicles during periods of lower demand for urban parcel delivery. With DRT-CCAM, we refer to CCAM-enabled DRT services.

The objective of the validation exercises is to analyse the impact of the implementation of different integration and coordination strategies in scenarios of increasing complexity. The scenarios considered are:

1. **Baseline scenario**: DRT-CCAM and parcel delivery services working as two independent services.
2. **Initial integration scenario**: routes for the combined service are defined uniquely based on the DRT-CCAM demand and DRT-CCAM user's needs, and only parcels that fit those routes are integrated.
3. **Optimized integration scenario**: routes for the combined service are defined based on the demand and needs of both services. In turn, in this case two sub-scenarios are considered for route optimization, both prioritizing passenger demand:
    a. routes are defined without constraints in the parcel delivery time,
    b. routes are constrained to parcel delivery time windows.

One of the requirements of this UC is that the new service ensures adhesion to people's transport schedule, avoiding impacting on the passenger transport service regular operations. Hence, in all the scenarios considered, the passengers' demand is the priority.

Then, the validation exercises are defined based on comparisons between these scenarios as follows:

1. Validation exercise #01 compares the baseline scenario with the initial integration scenario.
2. Validation exercise #02 compares the initial integration scenario with the optimized integration scenario without constraints to parcel delivery time windows.
3. Validation exercise #03 compares the initial integration scenario with the optimized integration scenario with constraints to parcel delivery time windows.

As a by-product, the results of exercises #02 and #03 are compared to identify and analyse the advantages and disadvantages of each optimized integration method.

These exercises will allow us to analyse and identify under which circumstances acceptable levels of adherence to passenger demand are maintained. Moreover, the socioeconomic, environmental, and operational impact analysis of each integration level will allow the definition of implementation policies leading to optimal coordination strategies.

The three validation exercises will be purely simulated using the transport simulators Aimsun Ride and Aimsun Next, for the Madrid city network (Figure 5).

Figure 5 - Zoom in of a sample of the Madrid city network

4.5.1 Validation exercise #01

Validation exercise description

In this exercise, a quite basic integration strategy is implemented in which DRT-CCAM routes are only affected by package pickup and drop-off times, but not by their locations, i.e., this first integration scenario only affects the duration of the route, but not its itinerary.

As the combined service should ensure adhesion to passengers' transport schedules, the objective of this exercise is to measure and assess the impact of this soft coordination strategy on those schedules, comparing it to the baseline scenario, and on the operations of the last-mile delivery services (e.g., number of parcels delivered, reduction of the number of delivery vehicles used, etc.)

The idea is that the assessment results of this soft integration guide the optimized integration strategies of the subsequent scenarios, identifying the main aspects to take into account or reinforce.

Validation Scenarios

The reference scenario in this case is the baseline scenario in which there are two services (DRT-CCAM and parcel last-mile delivery services) operating independently in the area.

The solution scenario corresponds to the initial integration scenario, in which a first coordination strategy is implemented and those parcels which pick-up and drop-off locations and times fit any of the routes defined based on the DRT-CCAM demand are delivered in the integrated service.

Validation exercise platform / tool and validation technique

To conduct this exercise, the following components are required:

- Last-mile delivery demand estimation component: the estimated demand of the last-mile delivery services will be generated using the *Data Fusion for Travel Demand Estimation and Characterization* component, which is being developed by Nommon.
- DRT-CCAM demand estimation component: the estimated demand of the DRT-CCAM services will be generated using the *Shared Mobility Demand Forecast & Mode Substitution Model* component, which is being developed by Nommon.
- Integrated DRT-CCAM and delivery demand optimization component: once the estimated demand of both services is generated, optimal demand-supply balancing strategies are applied to obtain the optimal routes for each scenario. These optimal routes will be generated through the *Hierarchical traffic scheduling and control of CAVs routes* and *Integrated On-demand and transit modes optimization* components, which are being developed by Deusto.
- Simulation platform: Once the optimal routes for the DRT-CCAM and parcel delivery service are derived, the services will be evaluated through simulation using the Aimsun Ride and Aimsun Next tools. The interactions between the service and the "background" traffic will be captured through simulation.

Once the simulations are performed, different statistics can be retrieved. This information, together with the optimization algorithm solutions will be used to compute the KPIs for each scenario.

Data collection and analysis

The data collected during the exercise will come from the outputs of the last-mile delivery and DRT-CCAM demand modules, the optimization algorithm, and the simulations performed. They will consist of tabular data in JavaScript Object Notation (json) and .csv format containing the optimal routes information (passengers and parcels pick-up and drop-off timestamps and locations), as well as the path followed. These quantitative data will be post-processed to compute the KPIs.

Additionally, a survey will be distributed among the identified stakeholders to measure the *Acceptance of ride-parcel-pooling* and *Average costs per parcel delivered & passenger* KPIs. The information for the first KPI will be qualitative, while for the second one, quantitative.

To compare both scenarios and analyse the impact of the initial integration strategy, the KPIs of both scenarios will be compared. Based on that, conclusions will be drawn.

Participants

The participant partners in this validation exercise are Nommon, Deusto, and Aimsun. Their role within the exercise is decribed below.

- Nommon will generate the demand data of both services and will perform the analysis of the results.
- Deusto will apply their optimization algorithms to define the optimal routes for each scenario and service.
- Aimsun will perform the simulation to assess the performance of the services using Aimsun Ride.

Exercise planning

The planning of this exercise is contained in Table 39.

Table 39 - Planning for exercise #1 - UC3

Exercise	Activity	Partner	Months					
			21	22	23	24	25	26
#01	Definition of spatial and temporal scope	All	■					
	Demand data generation	Nommon	■					
	DRT and last-mile routes generation for the baseline scenario	Deusto		■	■			
	Routes generation for the initial integration scenario	Deusto		■	■			
	Traffic simulation for the baseline scenario	Aimsun			■	■	■	
	Traffic simulation for the initial integration scenario	Aimsun				■	■	
	KPI computation	All					■	■
	Analysis of results and conclusions	Nommon					■	■

Identified risks and mitigation actions

Table 40 contains the list of risks associated to validation exercise #01, showing their severity and likelihood and the corresponding mitigation actions.

Table 40 - Identified risks for exercise #01 - UC3

Risk	Impact (1-low, 2-medium, 3-high)	Likelihood (1-low, 2-medium, 3-high)	Criticality (as the product of likelihood and impact)	Mitigation action

Components are not ready for the validation exercise	3-high	2-medium	6	The algorithms are being iteratively developed and tested in a set of scenarios of increasing complexity
Not enough data available	3-high	2-medium	6	The use of agile development methodologies allows the obtention of valuable results and data soon that will be further developed in successive iterations

4.5.2 Validation exercise #02

Validation exercise description

In this exercise, the impact of including one more level of complexity in the integration strategy is evaluated, considering the demand of both DRT-CCAM and last-mile delivery services to define the optimal routes for the combined service. For this second iteration of the integration process, we still maintain a certain degree of flexibility when defining optimal routes, since the parcel delivery time window is not taken into account. Furthermore, in the event of a conflict between both demands, passenger demand is prioritized.

The objective of this exercise is to analyse how this advanced level of integration affects the operations of both services, considering not only the adherence to passengers' transport schedules, but also the level of demand of each service covered by the coordinated system. To evaluate this impact, the performance results of this scenario are compared to those of the initial integration scenario.

From this comparison, the socioeconomic, environmental, and operational impact of an advanced integration of both services can be analysed, and trade-offs between KPIs can be identified.

Validation Scenarios

For this validation exercise, the reference scenario is the initial integration scenario, where a basic integration is already considered in which those parcels which pick-up and drop-off locations and times fit any of the routes defined based on the DRT-CCAM demand are delivered with the combined service.

The solution scenario corresponds to the optimized integration scenario without constraints in the parcel delivery time. In this case, a refined integration process is considered in which routes are defined based on the demand of both services, but prioritizing passenger demand, and without constraints in the parcel delivery time windows. This allows higher flexibility for adhesion to passenger’s optimal schedule.

Validation exercise platform / tool and validation technique

To conduct this exercise, the following components are required:

- Last-mile delivery demand estimation component: the estimated demand of the last-mile delivery services will be generated using the *Data Fusion for Travel Demand Estimation and Characterization* component, which is being developed by Nommon.
- DRT-CCAM demand estimation component: the estimated demand of the DRT-CCAM services will be generated using the *Shared Mobility Demand Forecast & Mode Substitution Model* component, which is being developed by Nommon.
- Integrated DRT-CCAM and delivery demand optimization component: once the estimated demand of both services is generated, optimal demand-supply balancing strategies are applied to obtain the optimal routes for each scenario. These optimization strategies will be applied through the *Fusion of DRT passengers and freight data* component, which is being developed by TUM. The routes for the combined service are generated with the *Ride-Parcel-Pool (RPP) Service* component, which is being developed by TUM as well.
- Simulation platform: The simulation is carried out in a co-simulation of FleetPy and Aimsun Next using the *FleetPy-Aimsun bridge* component. The bridge is being developed by TUM. In this co-simulation, the routes are calculated by FleetPy and transmitted to Aimsun Next for traffic simulation. FleetPy is an open-source python-based simulation framework for DRT services developed by TUM, and continuously enhanced by TUM for the UC.

Once the simulations are performed, different statistics can be retrieved. This information, together with the optimization algorithm solutions will be used to compute the KPIs for each scenario.

Data collection and analysis

The data collection process of this exercise is the same as that of exercise #01. As in that exercise, the KPIs of both scenarios will be compared to analyse the impact of the optimized integration strategy without delivery time constraints. Based on that, conclusions will be drawn.

Participants

The participant partners in this validation exercise are Nommon, TUM, and Aimsun. Their role within the exercise is described below.

- Nommon will generate the demand data of both services and will perform the analysis of the results.
- TUM will generate the optimized routes for both scenarios and will perform the traffic simulations to retrieve the needed statistics and KPIs.
- Aimsun will support TUM in the traffic simulation tasks.

Exercise planning

The planning of this exercise is contained in Table 41.

Table 41 - Planning for exercise #02 - UC3

Exercise	Activity	Partner	Months									
			24	25	26	27	28	29	30	31	32	33
#02	Definition of spatial and temporal scope	All	■									
	Demand data generation	Nommon	■	■	■							
	Routes generation and traffic simulation for the initial integration scenario	TUM		■	■	■	■	■				
	Routes generation and traffic simulation for the optimized integration scenario without constraints	TUM		■	■	■	■	■				
	Support TUM with the traffic simulations for the initial integration scenario	Aimsun		■	■	■	■	■				
	Support TUM with the traffic simulations for the optimized integration scenario without constraints	Aimsun		■	■	■	■	■				
	KPI computation	All					■	■	■	■	■	
	Analysis of results and conclusions	Nommon									■	■

Identified risks and mitigation actions

Finally, Table 42 contains the list of risks associated to validation exercise #02, showing their severity and likelihood and the corresponding mitigation actions.

Table 42 - Identified risks for exercise #02 - UC3

Risk	Impact (1-low, 2-medium, 3-high)	Likelihood (1-low, 2-medium, 3-high)	Criticality (as the product of likelihood and impact)	Mitigation action
Components are not ready for the validation exercise	3-high	1-low	3	The algorithms are being iteratively developed and tested in a set of scenarios of increasing complexity
Not enough data available	3-high	1-low	3	The use of agile development methodologies allows the obtention of valuable results and data soon that will be further developed in successive iterations

4.5.3 Validation exercise #03

Validation exercise description

Finally, the last validation exercise considers the most complete level of integration, including the delivery time window in the definition of the routes. This refinement ensures higher predictability of deliveries.

The objective of this exercise is to analyse the impact on both services (DRT-CCAM and last-mile delivery) of a refined and enhanced version of the optimized integration strategy considered in the previous validation exercise, in which uncertainty of parcel delivery time is reduced, which translates into an increase in the predictability of the complete coordinated service. This integration level leads to a lower degree of flexibility in routes definition, which can impact travel times and adherence to travel schedules. However, as in the previous validation exercise, in the event of a conflict between both demands, passenger demand is prioritized.

To evaluate this impact, the performance results of this scenario are compared to those of the initial integration scenario. From this comparison, the socioeconomic, environmental, and operational impact of a complete integration strategy of both services can be analysed, and trade-offs between KPIs can be identified.

Validation Scenarios

In this case, the reference scenario is the same as in exercise #02, the initial integration scenario, in which a basic integration is already considered.

The solution scenario corresponds to the optimized integration scenario with constraints in the parcel delivery time. For this last exercise, a more complex and complete integration process is considered in which parcel delivery time windows are also taken into account to define the optimal routes. Nevertheless, in this case, we still prioritize passenger demand.

Validation exercise platform / tool and validation technique

This exercise requires the same components as exercise #01. As in that exercise, the information needed to compute the KPIs will be retrieved from the Aimsun Next and Aimsun Ride simulations and the optimization algorithm solutions.

Data collection and analysis

The data collection process of this exercise is the same as that of exercise #01. As in that exercise, in order to compare both scenarios and analyse the impact of the optimized integration strategy with delivery time constraints, the KPIs of both scenarios will be compared. Based on that, conclusions will be drawn.

Participants

The participant partners in this validation exercise are Nommon, Deusto, and Aimsun. Their role within the exercise is described below.

- Nommon will generate the demand data of both services and will perform the analysis of the results.
- Deusto will apply their optimization algorithms to define the optimal routes for each scenario and service.
- Aimsun will perform the simulation to assess the performance of the services using Aimsun Ride.

Exercise planning

The planning of this exercise is contained in Table 43.

Table 43 - Planning for exercise #03 - UC3

Exercise	Activity	Partner	Months									
			24	25	26	27	28	29	30	31	32	33
#03	Definition of spatial and temporal scope	All	■									
	Demand data generation	Nommon	■	■	■							

	Routes generation for the initial integration scenario	Deusto										
	Routes generation for the optimized integration scenario with constraints	Deusto										
	Traffic simulation for the initial integration scenario	Aimsun										
	Traffic simulation for the optimized integration scenario with constraints	Aimsun										
	KPI computation	All										
	Analysis results and conclusions	Nommon										

Identified risks and mitigation actions

Finally, Table 44 contains the list of risks associated to validation exercise #03, showing their severity and likelihood and the corresponding mitigation actions.

Table 44 - Identified risks for exercise #03 - UC3

Risk	Impact (1-low, 2-medium, 3-high)	Likelihood (1-low, 2-medium, 3-high)	Criticality (as the product of likelihood and impact)	Mitigation action
Components are not ready for the validation exercise	3-high	1-low	3	The algorithms are being iteratively developed and tested in a set of scenarios of increasing complexity

Not enough data available	3-high	1-low	3	The use of agile development methodologies allows the obtention of valuable results and data soon that will be further developed in successive iterations

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ABBREVIATIONS AND DEFINITIONS

Acronym	Definition
API	Application Programming Interface
BAU	Business as usual
CAV	Connected and Automated Vehicles
CAM	Cooperative Awareness Message
CCAM	Connected and cooperative autonomous mobility
CO2	Carbon Dioxide
CP	Continuous Planning
CPU	Central Processing Unit
CSV	Comma-separated values
DBL	Dedicated bus lane
DP	Demand prediction
DRP	Demand Responsive Transport Platform
DRT	Demand-responsive transport
ETA	Estimated Time of Arrival
GDPR	General Data Protection Regulation
GHG	Greenhouse gas
GLOSA	Green Light Optimized Speed Advice
GTFS	General Transit Feed Specification
HDV	Heavy-duty vehicle
ID	Identification
IDE	Integrated Development Environment
ISO	International Organization for Standardization
iTLC	Intelligent Traffic Light Controller
json	JavaScript Object Notation
KPA	Key Performance Area
KPI	Key Performance Indicator
MARL	Multi-Agent Reinforcement Learning
ML	Machine Learning
NOx	Oxides of Nitrogen
O	Objective
OD	Origin-Destination
RAM	Random access memory
REST	Representational State Transfer
RPP	Ride-Parcel-Pool
SIRI SM	Stop Monitoring service

SPAT	Signal Phase and Timing
TBD	To be defined
UC	Use Case
Veh/s	Vehicles per second
VMS	Variable Message Signs
VSMACV	Vehicle Scheduling Model for Autonomous and Connected Vehicles
V2I	Vehicle to Infrastructure
WP	Work Package