Fleet and traffic management systems
for conducting future cooperative mobility

D5.4 Report on Impact Assessment of Use Cases

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1 EXECUTIVE SUMMARY

The CONDUCTOR project aims to design, integrate and demonstrate advanced, cooperative fleet and traffic management solutions to enhance the efficiency, sustainability and reliability of both passenger and freight transport. Building on the validation activities carried out in the Use Cases (UCs), this D5.4 presents the final impact evaluation of the CONDUCTOR solutions, translating validated Key Performance Indicators (KPIs) into tangible societal, environmental and economic benefits. The results and KPI values were all taken from D5.3[3] *Report on Use Cases execution and their validation*.

The assessment applies the methodology and framework defined in D5.2[2], aligned with the EU Common Evaluation Methodology (EU-CEM)[8], across six Key Performance Areas (Technical, Social, Environmental, Economic, Human Performance and Liability). Quantitative results were complemented with qualitative findings to provide a comprehensive view of the effectiveness, scalability and policy relevance of the CONDUCTOR solutions.

Across all pilots, the project demonstrates measurable improvements in transport efficiency, emissions and operational reliability. In particular:

- **Athens (UC1):** multimodal traffic management improved efficiency and reliability, yielding more than €8’100’000 economic benefit yearly for the studied corridor, as well as significant GHG reductions for the transport sector.
- **Almelo (UC1):** conditional freight-priority management improved corridor efficiency and reduced emissions, yielding economic and operational benefits (for logistics operators) and offering a replicable governance model.
- **Madrid (UC1):** CAV-enabled incident management enhanced network resilience and travel-time reliability, improving safety and coordination while demonstrating scalable integration of automated-vehicle data into city traffic-management systems.
- **Slovenia (UC2):** automated demand-responsive transport (DRT) optimisation improved efficiency, reliability and scalability, reducing costs and manual effort while strengthening regional integration of demand-responsive mobility services.
- **Madrid (UC3):** integrated passenger-freight operations, improved fleet efficiency and asset utilisation, and demonstrating cross-sector scalability for combined mobility and logistics services.

Collectively, these results confirm that CONDUCTOR solutions deliver verified efficiency gains, environmental benefits and economic improvements. This is aligned with the initial impact expectations on traffic efficiency improvements and interoperability and seamless mobility, as described in the call topic.

Three overarching lessons emerge for urban-mobility policy:

1. Data integration and interoperability are decisive factors for efficiency and environmental performance.
2. Institutional cooperation ensures scalability and governance continuity beyond pilot stages.
3. Human-centred automation sustains safety, trust and legal acceptability in CCAM deployment.

For cities and operators, the results translate into a clear to-do list: integrate CCAM tools into existing Traffic Management Centres and Sustainable Urban Mobility Plans (SUMPs), establish multimodal data-sharing frameworks, provide operator training for human-machine collaboration and adopt harmonised monitoring through EU-CEM[8] and Urban Mobility Indicators.

In summary, CONDUCTOR validates a coherent set of cooperative and automated traffic-management solutions that demonstrably enhance efficiency, reduce emissions and strengthen governance capacity.

2 INTRODUCTION

2.1 Context

D5.4 reports on the evaluation and interprets the impacts generated through the CONDUCTOR project's UCs. It is part of Task T5.5 "Impact assessment", within Work Package 5 (WP5) "Validation of cooperation and governance", with its delivery due at the end of the overall project, in month 36.

This document is directly related to the following WP5 deliverables:

- D5.1[1], where the Validation Strategy and objectives were established.
- D5.2[2] "Impact evaluation framework and dedicated KPIs", which built on this strategy, setting the framework for the Impact Assessment.
- D5.3[3] "Report on Use Cases execution and their validation", which follows a parallel timeline with D5.4 and provides a compilation of the results of the UCs, used in the Impact Assessment calculations.

The logic chain is represented in Figure 1:

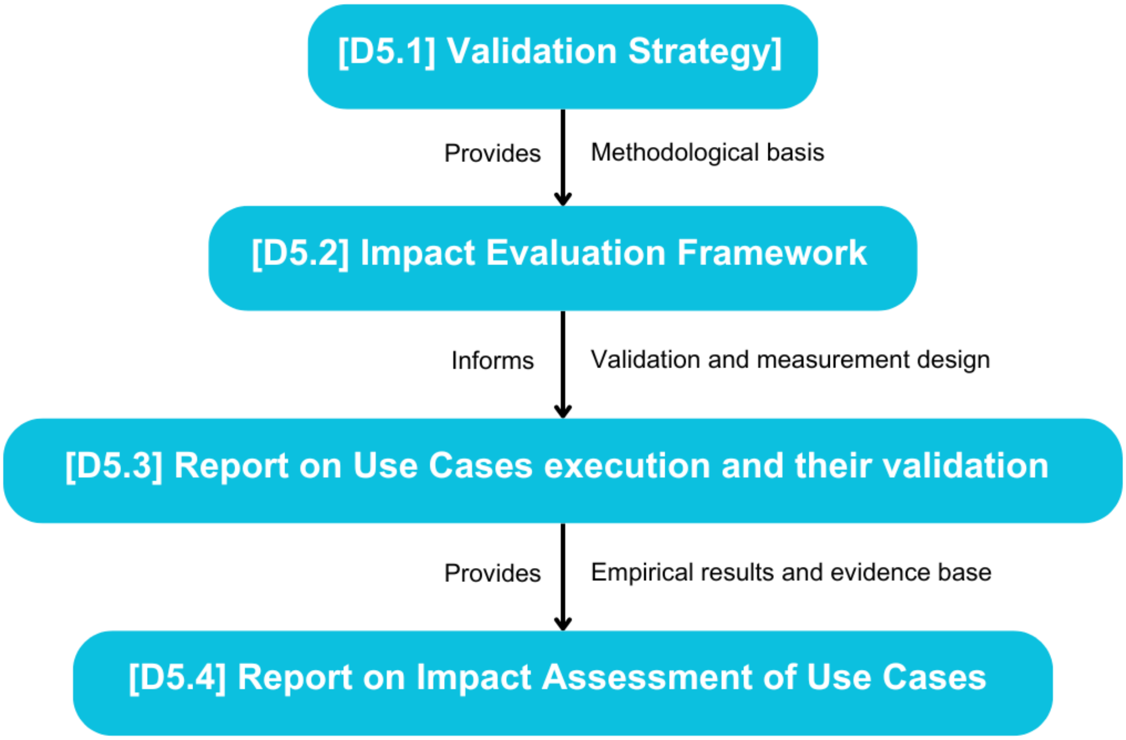

Figure 1: Logic Chain of the Impact Framework

2.2 Scope of D5.4

The Impact Evaluation assesses the different traffic management-solutions in the field of Connected Cooperative & Automated Mobility (CCAM) that were tested across the three UCs of the CONDUCTOR project. As visualised in Figure 2, quantitative and qualitative impacts on various stakeholders are considered, forming six Key Performance Areas (KPAs):

- Technical Impact
- Social (Societal) Impact
- Environmental Impact
- Economic Impact
- Impact on Human Performance
- Impact on Liability

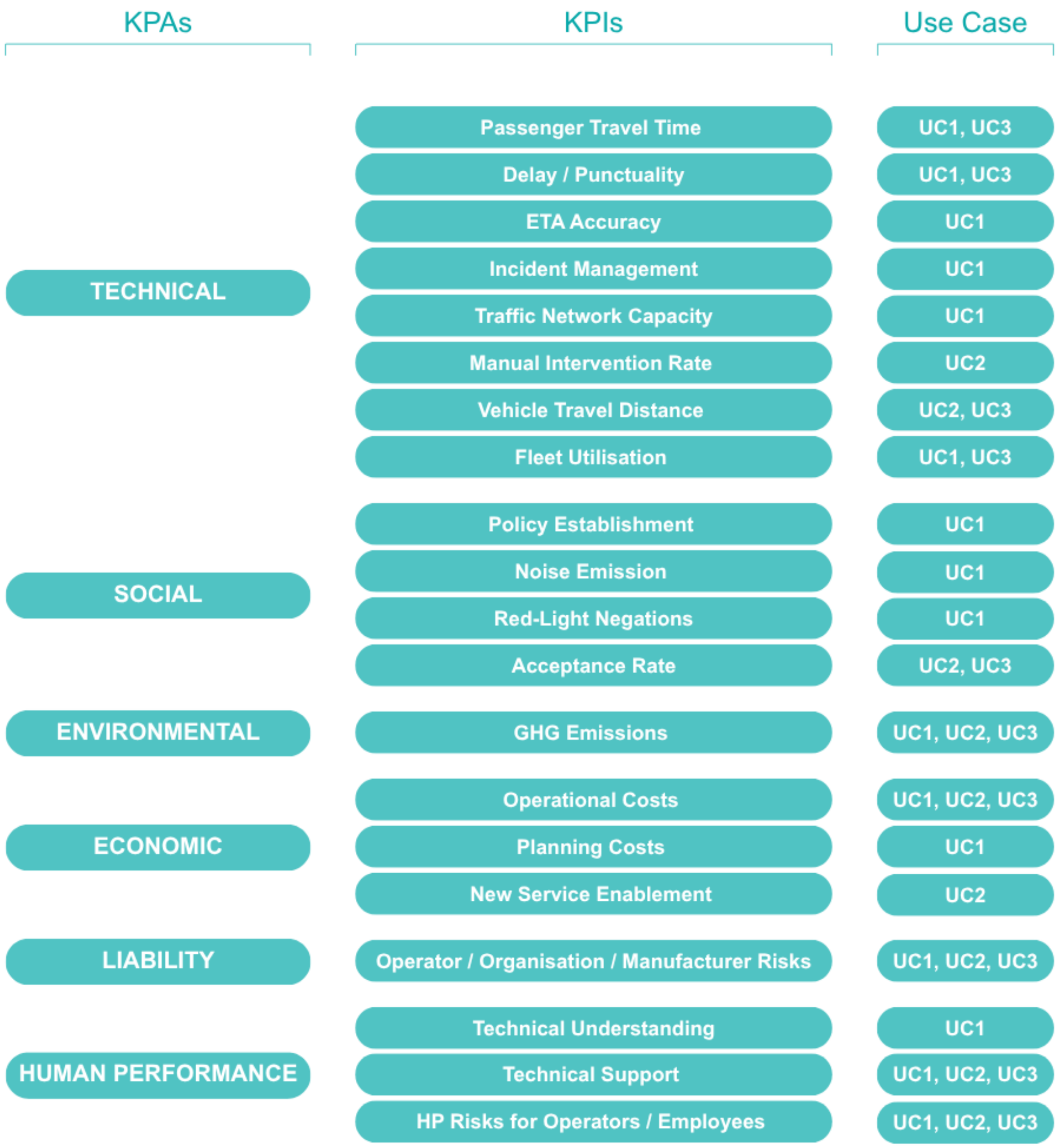

Figure 2: Overview of KPAs & KPIs

The deliverable aims at various stakeholders, mainly from the CCAM-community, as well as those involved in the Horizon Europe Work Programme. First and foremost, it addresses the CONDUCTOR-consortium and especially the European Commission (EC) reviewers. Interested stakeholders, such as city authorities, fleet operators and further CCAM suppliers can also be considered relevant readership. Furthermore, as already reported in D5.1[1], the following stakeholders might also be interested in the results:

- CCAM program 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 into 6 sections, outlined as follows:
Section 1 Executive Summary summarises the key objectives and scope of the deliverable, including a brief overview of the impact evaluation's results.
Section 2 Introduction contextualises deliverable D5.4 and defines its scope.
Section 3 Methodology presents the Impact Assessment's methodology, in alignment with both D5.2[2] Impact Evaluation Framework and Dedicated Key Performance Indicators (KPIs), and benchmark frameworks such as the CCAM EU-CEM[8] policy evaluation framework. The Section also provides clarifications regarding the interpretation of the results into quantifiable impact.
Section 4 Evaluation and Impact Assessment present the different UCs and the respective solutions implemented. Further elaboration is made on the defined KPAs and KPIs, while the respective impacts are contextualized and benchmarked against other reference projects. The process is repeated for every UC.
Section 5 Cross-use case synthesis provides a cross-comparison between the UCs. Patterns and extreme cases of the results are pointed out, comparative insights are highlighted, and correspondence to the cities' and involved stakeholders' visions are assessed.
Section 6 Conclusion summarises the results and the detected impacts. On this basis, lessons are drawn for urban mobility policies and operators regarding future CCAM roll-outs.

3 METHODOLOGY

3.1 Recapitulation of logic chain (D5.2)

Impact Framework
The impact assessment follows the “CONDUCTOR Impact Framework”, developed in deliverable D5.2[2]. The foundation for the methodology was established in D5.1[1] (Task 5.4), comprising 3 main steps:

1. KPAs
2. Validation Objectives
3. KPIs, Success Criteria, Data Collection Methods

Next, D5.2[2] “Impact Evaluation Framework” assesses or monetises results and aggregates them, grounded in the metrics, baselines, and success criteria. More specifically, D5.1[1] sets the metrics, describes the respective measurement processes and forms the success benchmarks. D5.2[2] then translates those validated KPIs into quantified societal, environmental, and economic impacts, often through monetisation (e.g., € per ton CO_2, € per passenger-hour saved). The Final Impact assessment builds upon D5.1[1] and D5.2[2] by aggregating the validated results.

3.1.1 Liability & Human Performance

Expanding on the D5.2[2] impact framework, aspects that are not directly quantifiable have also been made part of the impact assessment. This applies especially to Liability and Human Performance aspects, which were not included in the original D5.2[2] framework. In this regard, an adjustment has been made, which is also represented in Figure 2.

3.2 Pathways toward impact

In total, the impact assessment paves the way for a potential broader adoption of the CCAM-solutions tested throughout the UCs in CONDUCTOR.
For each KPI of each UC, a base-value is established, corresponding to the state before the CONDUCTOR solution was introduced. The baseline is then compared to the post-pilot state. Where KPI-results are expressed quantitatively or where quantification is possible, the impact assessment documents the percentage of growth/savings/etc., by applying the Simple Delta method:

- Percentage change = (Post-pilot – Baseline) / Baseline × 100%

After KPI validation and impact assessment, D5.4 proceeds with exploring their respective correspondence to the cities’ and stakeholders’ goals, and the exploitation emphasised accordingly. The latter is conducted in the deliverable D6.2[4]. This pathway, already outlined in D5.2[2], is illustrated in Figure 3.

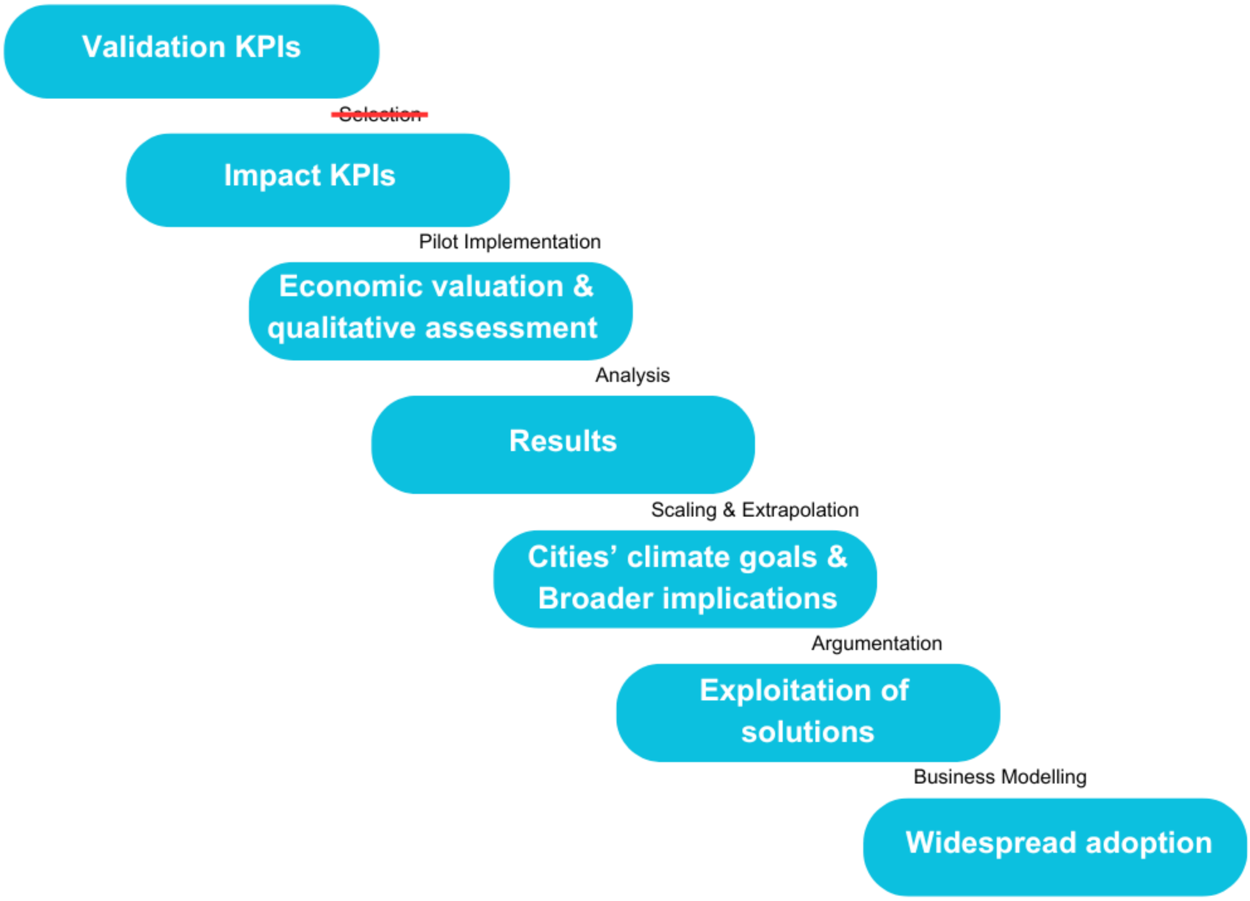

Figure 3: Adjusted pathway to impact

3.2.1 Impact Interpretation

Monetizable KPIs

A large proportion of the KPIs are reported in a quantitative form or they can be quantified. These KPIs are monetised, i.e., translated into economic value, according to the Handbook on the external costs of transport[5], the EC's standard source for cost-benefit analyses in transport and widely recognised across Horizon projects.

Non-monetizable KPIs

Non-monetizable impacts are assessed in a different manner. In accordance with the EU-CEM[8], these are evaluated under:

- Technical performance (reliability, robustness, predictability)
- User interaction (trust, satisfaction, usability)
- Governance (liability, acceptability)

Translation into Impact

The last step in assessing the CONDUCTOR impacts is summarising the tangible effects of the UC solutions. This involves a qualitative interpretation of the solution's implementation's impacts. The impact evaluation for each KPI unfolds along three axes:

- Project-internal ("Success Criteria")
- Stakeholders impacted
- Summary & qualitative assessment

Last, if possible, the results and impacts of each UC are compared to reference projects and benchmarks, highlighting, thus, the significance and magnitude of the impacts.

Scenario-development (*adjusted*)
The initial intention of scenarios considered for comparison purposes was as follows:
- Baseline scenario (pre-existing conditions),
- Business-as-usual scenario (BaU, without CONDUCTOR solution deployment),
- Post-pilot scenario (after CONDUCTOR solution deployment)

However, the data gathered in the UCs does not allow to also forecast a future scenario without the introduction of the CONDUCTOR solutions. Since the initial expectations on data collection and requirement were eventually not met, the BaU scenario is not considered (see adaption in Figure 4).

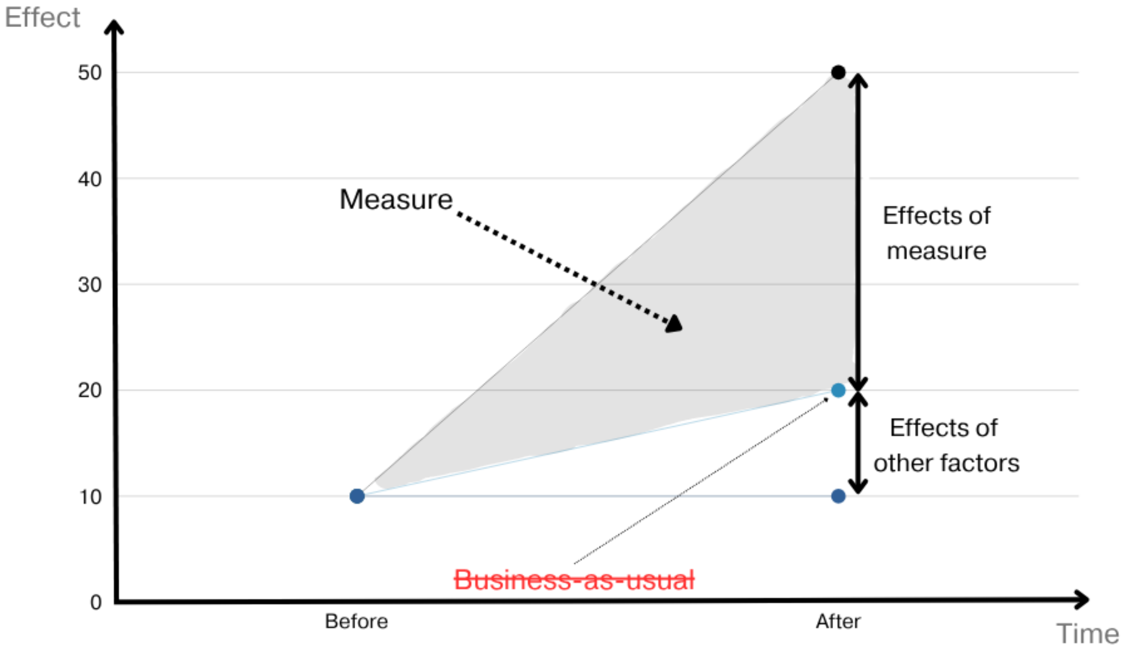

Figure 4: Scenario development (adjusted)

Large-scale Impact
On this basis, the findings are aggregated at different levels (e.g., pilot-level, city-level) and then compared with respect to their correspondence to the cities' and stakeholders' expectations for each UC. This methodology is aligned with the Common Evaluation Methodology for CCAM (EU-CEM[8]), Key Impact Pathways (KIPs), and Urban Mobility Indicators (UMIs)[9] for standardisation and comparability.
This ensures comparability and provides data in support of a wider adoption of CONDUCTOR solutions. The impacts are meant to support business models, exploitation roadmaps, and policy uptake at European Union (EU) and city levels.

Following the approach outlined in the project proposal, the large-scale impact assessment is based on three different scenarios:
- *Conservative*: direct implementation of solutions and deployment of demonstrators by CONDUCTOR partners, limited to the agreed location and scope, following regular growth expected in the sector and due to other project developments from a conservative side.
- *Ambitious*: uptake of solutions in other locations within project cities/sites, and outreach and cross-fertilization to other locations, via partners' networks, representing significant general growth.
- *Optimistic*: widespread uptake of results and solutions and positive spillover effects to additional cities, both via CONDUCTOR partners and external links.

3.3 Alignment and Learnings from Reference-Frameworks

CONDUCTOR's impact assessment joins the rank of Horizon Europe (HE) projects in the CCAM environment, particularly in Traffic Management. Accordingly, it is aligned with key references and tries to learn and benefit from them.

3.3.1 EU-CEM for CCAM

The EU-CEM[8] is designed to provide a structured, standardised evaluation of CCAM systems across Europe. The methodology covers both technical and societal impact assessments, and it ensures that results from different projects are harmonised, comparable, and transferable for decision-making and policy. Therefore, CONDUCTOR leverages the framework to ensure its results are robust, comparable, and transferrable to future CCAM research and deployments across Europe, allowing CONDUCTOR's outcomes to feed into broader EU policy and deployment frameworks.
CONDUCTOR's impact assessment comprises the afore-mentioned 6 KPAs. Instead, the EU-CEM[8] comprises 4 Evaluation Levels, under which 18 Evaluation Areas are mapped (cf. Figure 5):

- Vehicle
- Human
- Transport System
- Society

Figure 5: EU-CEM Evaluation Areas (Source: EU-CEM)

CONDUCTOR's KPAs are broader in scope, while the EU-CEM[8] evaluation areas correspond to more refined categories. Still, the mapping of the two can be described as in Table 1:

Table 1: EU-CEM mapping

CONDUCTOR KPA	EU-CEM Evaluation Areas
Technical	Vehicle – *Technical functioning*
	Vehicle – *Driving behaviour*
	Transport system – *Services and operation*
	Transport system – *Traffic flow efficiency*
Social	Human – *User**
	Human – *People mobility**
	Human – *Quality of life*
	Transport system – *Accessibility*
Environmental	Transport system – *Energy and environment*
	Society – *Liveability*
Economic	Society – *Economic activity and employment*
	Society – *Socio-economics**
	Society – *Equity**
	Transport system – *Logistics*
Human Performance	Human – *User**
	Human – *People mobility**
Liability	Society – *Equity**
	Society – *Socio-economics**

**Assigned to more than a single CONDUCTOR-KPA*

CONDUCTOR's KPAs are higher-level "clusters" of the EU-CEM[8] evaluation areas. They simplify the taxonomy while ensuring alignment. EU-CEM[8] provides granularity (vehicle / human / system / society), while KPAs provide a practical grouping for project-level validation and impact work.

3.3.2 IN2CCAM Twinning

The IN2CCAM project (Enhancing Integration and Interoperability of the CCAM ecosystem) represents a parallel Horizon Europe project, focusing on the integration of Connected, Cooperative, and Automated Mobility services into fleet and traffic management systems across six Living Labs in Europe (Tampere, Trikala, Turin, Vigo, Bari, and Quadrilátero). Its methodological framework for impact assessment, defined in Deliverable D5.1[17], adopts a Multi-Criteria Decision-Making (MCDM) approach, particularly the Analytic Hierarchy Process (AHP), to weigh KPIs across seven impact areas (usage, quality of service, safety, efficiency, user acceptance, environmental, and economic). Within CONDUCTOR, the impact assessment similarly builds on a multi-dimensional evaluation across KPAs but prioritises quantified validation and monetisation rather than stakeholder-based weighting.

<u>Methodological alignment</u>
Both projects are similar in their KPI-driven frameworks, where KPIs are grouped into impact areas (beyond just technical). Also, both projects pursue an integrated assessment of CCAM-enabled interventions. However, they differ in their analytical focus and data processing approach:

- Different methodologies: While IN2CCAM[17] applies AHP-based stakeholder weighting to evaluate the relative significance of KPIs, CONDUCTOR quantifies absolute impacts through pilot data validation and monetisation. This distinction limits direct comparability of numerical results but ensures methodological complementarity within the CCAM Partnership[10].

- Comparable results: Where scope and/or location overlap, comparable outcomes can be referenced to cross-validate trends (e.g. reductions in travel time, emissions, or improved coordination between connected fleets). The cross-comparison with IN2CCAM and the performance of the KPIs in the IN2CCAM project are revisited in the Conclusion chapter, to support joint interpretation and policy alignment between the two projects.

3.3.3 MTM

CONDUCTOR's UC and validation approaches map the goals and pillars of the Multimodal Traffic Management (MTM) Cluster. The CONDUCTOR project can be considered a member of / contributor to the MTM Cluster, and the pilot-level experiments mirror the cluster's pillars of technology, data, and governance. MTM components can be found throughout all UCs.

3.3.4 KIPs

Additionally, the CONDUCTOR impact assessment is also aligned with the Horizon Europe KIPs. Monetizable KPIs (time, fuel, emissions) contribute directly to the economic and environmental KIPs, while non-monetizable KPIs (ETA accuracy, incident management, liability, governance, human performance) are assessed through quantitative improvements and qualitative evaluation, contributing to societal KIPs, e.g., inclusivity, safety, and resilience. This ensures that both tangible external cost reductions and enabling conditions for CCAM adoption are captured in the assessment, in line with EU-CEM[8] recommendations.

3.3.5 UMIs

Lastly, the impact assessment is also aligned with the UMIs[9] defined under the Trans-European Transport Network (TEN-T) regulation. While CONDUCTOR KPIs are tailored to pilot-specific interventions, they map directly onto the UMI[9] domains: accessibility (transfer reliability, demand served), sustainability (CO_2/NO_X reduction, idle km avoided), safety (road safety, incident management), efficiency (travel time, service reliability), and governance/digitalisation (liability, human performance, pooling acceptance). This ensures comparability with city-level monitoring obligations under SUMPs and TEN-T urban nodes.

4 EVALUATION AND IMPACT ASSESSMENT

This chapter, reports on the results and their associated impacts for all UCs.

4.1 Use Case 1 Athens

Athens faces severe congestion, with public transport (metro, tram, buses, trolleybuses) needing better synchronisation to handle rising multimodal demand. UC1 focuses on integrated traffic management with inter-modality. The Athens pilot considered the optimal synchronization of bus and metro services by adjusting schedules to reduce travel times, while using traffic management and journey planning platforms to improve the reliability and flexibility of multi-modal journeys.

The results of the Athens UC are extensively reported in D5.3[3].

4.1.1 UC-specific methodology

Validation Exercise #1
In order to get a greater perspective from the results of the simulations and the real-time data of Validation Exercise #1, an extrapolation was conducted to assess the impact of the pilot on the overall city (center) of Athens. This regards the different scenarios from conservative to optimistic, presented in 3.2.1. The extrapolation was conducted in steps, as follows:

- Data reported for trips on the studied corridor during rush hours (7am-10am).
- Extrapolation from rush-hour trips to hourly trips in the studied area, applying the hourly factors (cf. **Error! Reference source not found.**).
- Extrapolation from hourly trips to daily trips (cf. **Error! Reference source not found.**).
- Extrapolation from daily trips to yearly trips, by applying a factor of 365 (days), and by calibrating the demand of an average day by a factor of 0.9293. This addresses the need to consider varying traffic and passenger demand patterns (e.g., seasonal variations, including weekends and holidays).
- Extrapolation from the studied corridor of Alexandras Avenue to the whole city center of Athens, by applying a factor of 5.6. The overall traffic count of a typical 3-hour morning rush hour (7am - 10am) in Athens' city center is approximately 186'300 trips. In UC1 - Athens, approximately 33'400 trips occur in the same timeframe. Accordingly, the trips captured in the UC represent 15-20% of Athens city center's rush hour traffic.

Table 2: UC1 Athens demand profile (Validation Exercise #1)

Time	Demand factor
0:00 - 1:00	0.10
1:00- 2:00	0.03
2:00 - 3:00	0.02
3:00 - 4:00	0.02
4:00 - 5:00	0.04
5:00 - 6:00	0.18
6:00 - 7:00	0.50
7:00 - 8:00	0.89
8:00 - 9:00	1.00
9:00 - 10:00	0.95
10:00 - 11:00	0.85
11:00 - 12:00	0.93

12:00 - 13:00	0.89
13:00 - 14:00	0.95
14:00 - 15:00	0.92
15:00 - 16:00	0.95
16:00 - 17:00	0.75
17:00 - 18:00	0.94
18:00 - 19:00	0.93
19:00 - 20:00	0.88
20:00 - 21:00	0.83
21:00 - 22:00	0.75
22:00 - 23:00	0.48
23:00 - 24:00	0.40

Validation Exercise #2
Validation Exercise #2 was originally designed for Athens but, due to the lack of reference ETA predictions, the exercise was conducted in the Netherlands using Connexxion GTFS feeds. The setup replicated Athens routes and operational conditions as closely as possible, allowing evaluation of the Ridango ETA algorithm under comparable circumstances.

Validation Exercise #3
In order to get a greater perspective of the results, a large-scale application of the Vehicle Scheduling Model for Autonomous and Connected Vehicles (VSMACV) for the overall PT-network is extrapolated, to assess the larger-scale impact of the pilot. The optimistic scenario assumes the solution being applied to all feeder lines that possibly meet the requirements of the VSMACV and connect to / support the metro / trunk PT-routes. There are about 184 feeder lines. For the optimistic scenario-estimation, 180 is used, along with a small-scale variant (ambitious scenario) of 60, reflecting a small / moderate central subset of these lines.
In general, it is being sticked with the evening off-peak time window.
The extrapolation was conducted as follows:

- Data availability for trips of studied feeder-trunk relation available for low-frequency conditions at off-peak evening hours (19:00-24:00).
- 60 resp. 180 feeder lines in total
  - Ambitious scenario: 60 feeder lines
  - Optimistic scenario: 180 feeder lines
- Extrapolation from studied feeder line to the whole city center of Athens' feeder lines, by reference to Table 3.
- Extrapolation from daily off-peak evening hours to yearly impact on studied lines, by applying factor 365 (days), and calibration of the demand of an average day by factor 0.9293.

Table 3: UC1 Athens feeder lines (Validation Exercise #3)

Scenario	**# feeder lines**	**Additional passengers impacted per day**	**% of evening trips (assuming ca. 100k – 150k)**		**% of evening trips**	
			100'000	150'000		
Ambitious	60	7'200	0.072	0.048	7.2	4.8
Optimistic	180	21'600	0.216	0.144	21.6	14.4

4.1.2 KPA-/KPI-Results Athens

The following sub-chapters report on the KPIs and impacts associated with the collected results of UC1 Athens.

4.1.2.1 Technical KPA

Passenger/vehicle travel time

Impact
The results reveal an average reduction in passenger travel time (buses & private vehicles). Optimization values achieved a more than 11% reduction when compared to the baseline values. The implemented management strategy reduced vehicle travel times by more than 19%. On average more than 25 seconds are saved per trip. It is noted that more than 60’000’000 (million) yearly trips take place in the studied area. According to the Handbook on the external costs of transport[5], with respect to “short distance” (urban) trips in Greece, an hour of time saving is valued €9 / hour / person. Extrapolated to a year, that corresponds to an economic valuation of roughly €6.5 millions for the study-area alone. In the optimistic scenario, assuming implementation over the whole city center of Athens, an economic valuation of more than €30 million per year is yielded.

Interpretation
During the planning stage (D5.1[1]), when the UC was still described in generic terms, the success criterion for this KPI was set as a minimum of 3 minutes travel time saved per trip. The threshold is clearly not met, but this does not imply failure of the pilot. Simply, the margin was set too high, since the average trip duration before the introduction of the CONDUCTOR solutions (baseline value) was hardly above 3 minutes.
The model mainly impacts travellers, in other words, “clients” of the mobility system. Public Transport (PT) operators are also affected, since a reduction in travel times implies a rise in efficiency as travel time reliability increases, improving PT services. It can be concluded that all major stakeholders are impacted, due to PT demand being typically high as in every metropolitan area.
Making additional assumptions, financial gains can also be attributed to OASA, the Athens PT authority. PT accounts for ca. 22% of passengers in the simulated corridor. Considering, that the CTMS system particularly addresses PT-operation, it can be assumed that the gains for the directly affected PT-users are even stronger than reported for the overall KPI-result. With conservative calculations, the gains attributed to OASA rise up to 25%, which equals an economic valuation of €7.5 million/year on a city-wide scale. Despite this being significant, it constitutes only a small portion of OASA’s yearly budget (estimated between €300-450 millions), with the economic gains not directly benefitting OASA but rather its clients (time-savings).
Due to the benefit to key stakeholders, the assessment concludes on a relevant, significant impact on Travel Time Savings.

Passenger waiting time at transfer stops

Impact
The results reveal an overall reduction in passenger transfer waiting times (between feeder lines and trunk line). Compared to the baseline static optimisation approach, the dynamic VSMACV reduces total passenger transfer waiting times by more than 80%. This reduction has a significant impact on the average travel time per passenger, since waiting at the transfer stop is a major component of total travel time. In particular, the average transfer time per trip shrunk from ca. 10 minutes to less than 2 minutes, allowing for a reduction of more than 8 minutes. 7’362 seconds of total waiting times at transfer stops constituted the baseline value, which was reduced to 1’403 seconds. In 5 out of 12 (42%) feeder trips, seamless transfers (0 sec waiting time) were achieved. On the studied corridor, 12 trips/day occur, impacting ca. 10 passengers each, equalling 4’380 trips/year and 43’800 passengers impacted (conservative implementation scenario). Here too, according to the Handbook on the External Costs of Transport[5], in Greece, for short urban journeys, one hour of time saved is

valued €9 per hour per person. Extrapolating this to an ambitious scenario involving 60 feeder lines results in annual time savings valued at approximately €3 million. Under the optimistic scenario, where 180 feeder lines are covered, the yearly economic benefit rises to about €9.1 million, reflecting the significant potential of optimised transfers at network scale.

Interpretation

During the planning stage, the success criterion for this KPI was set as an improvement by a minimum of 3 minutes. This target was not only achieved but outperformed by more than a factor of 2. Mainly PT users are impacted by the model. PT demand is typically high, and transfers and associated waiting times along the journeys often prevent people from using the means. On the other hand, a reduction of transfer and, in general, travel times increases passenger satisfaction and possibly PT mode share.

The VSMACV, despite prioritising the minimization of transfer waiting times, it still manages to improve service regularity. Therefore, it improves the system's technical performance and fosters user trust in, satisfaction of and willingness to use the service. As such, the results of the exercise can be considered as having significant positive impacts. However, the assumptions of the exercise (consideration of off-peak evening hours, 12 feeder line journeys) limit the transferability of the findings, due to uncertainties regarding the possibility for an extrapolation.

<u>Punctuality of scheduled arrival/departure time</u>

Impact

The results reveal an overall improvement in punctuality. The deviation of actual headways from target headways is reduced by almost 20% (-19.6%). Dynamic control, thus, improves punctuality and service regularity while maintaining transfer synchronisation. Further analyses have shown that, as optimisation progresses, headway deviation continues to decline. This confirms that irregularities are stabilised rather than amplified.

Interpretation

The success criterion for punctuality of scheduled arrival/departure time was set within a 5 minute range (300 seconds) of the scheduled time. All trips, except for trips 4 and 5, meet the 5-minute criterion, that is 10 out of 12 trips (83%) successfully meet the punctuality KPI.

As for the impacted stakeholders, these include the PT operators, since the model allows for transfer synchronisation between feeder lines (bus) and trunk lines (metro), as well as passengers, improving modal share and overall transport system performance.

Due to inability to conduct an accurate quantification of the impact of the results, it can be concluded, in more qualitative terms, that the KPI performs well, improving system reliability and user satisfaction.

<u>ETA-accuracy</u>

Impact

The results reveal an improvement in the ETA accuracy. Comparing the Ridango Algorithm (Post-pilot) to the baseline predictions (GTFS RT NL predictions), the ETA accuracy improved by 12.35%.

Interpretation

The success criterion for this KPI was defined as a 5-10% improvement. This goal was clearly accomplished, even outperformed.

There cannot be defined a specific category of stakeholders that benefit from the ETA prediction improvements, since this accomplishment favours all involved parties. Firstly, it is beneficial to PT-operators, who may offer more reliable services, increasing passenger satisfaction and possibly PT modal share. The potential modal shift's valuation is mainly expressed in externality-savings. The impact of more accurate ETA predictions may also be particularly significant in multimodal journeys. Despite the results not being quantifiable, they are considered significant, specifically in terms of enhancing user information and satisfaction, as also pointed out in the ORCHESTRA[14,15] project.

Incident management

Impact

The results reveal the successful integration of incident management tools with an addition of 5 extensive tools (configuration tools, APIs, action tools, notification systems, and diversion planning) into a single fleet management environment. While quantitative impacts (time, emissions) were not directly measured, the qualitative validation shows that the module substantially strengthens resilience and user trust in PT operations.

Interpretation

There was no success criteria defined regarding incident management.

The extra tools for incident management provide more efficiency to users, the main stakeholder benefitting being road authorities and PT operators.

The results cannot be quantified. In general, incident management may improve resilience and safety, reducing disruption and supporting inclusivity by safeguarding service continuity. This results in fewer cancellations and/or detours, which translate into quantifiable reductions in operational costs. It can be concluded that the integration of incident management tools improved technical performance.

4.1.2.2 Social KPA

Service accessibility & missed transfers

Impact

The results reveal a successful transfer synchronisation improvement. The study did not compute a full door-to-door travel time but explicitly links improved transfer synchronisation to shorter total passenger travel times. By minimising transfer waiting and eliminating missed connections, the VSMACV enhances overall accessibility and reduces the effective door-to-door travel duration for multimodal passengers. Average transfer times reduced by more than 8 minutes. Furthermore, unlike the baseline, where trips 4,5,7,8 were missed (33%), the dynamic VSMACV achieves 100% successful transfers. The result is a fully synchronised schedule, mitigating missed transfers, improving service accessibility.

Interpretation

The success criterion for this KPI was defined as the reduction of door-to-door travel time by at least 3 minutes. However, the actual exercise results do not correspond to door-to-door travel times but to transfer waiting times. As a result, a direct conclusion regarding the specific KPI cannot be drawn, despite the reduction in the average transfer time by 8 min implying a possible success regarding the benchmark. The results will primarily impact stakeholders involved in PT operations, policymaking, and end-user experience. Missed transfers directly impact passengers, causing delays, longer travel times, and frustration. Improved transfer synchronisation results in better service accessibility and more reliable connections. Reduced waiting times and the elimination of missed transfers improve passenger experience and satisfaction, making the system more attractive and reliable for users and indicate higher quality to PT operators and transport authorities.

Once again, the results are not quantifiable, despite leading to the conclusion of improved technical performance and user satisfaction.

4.1.2.3 Environmental KPA

CO_2-emissions

Impact

The results reveal a reduction in CO_2-emissions by more than 11%. In one typical rush hour, more than 1.1 tonnes (1’120kg) of CO_2 emissions are saved in the studied corridor. In a whole year, the implementation of the CONDUCTOR solutions saves more than 2'000 tonnes of CO_2 emissions. Applying climate change avoidance costs of €100/tonne for CO_2, extrapolated to a year, this translates into avoidance costs of more than €200'000 for the studied area and more than €1 million when extrapolated to the whole city center of Athens. Extrapolating the CO_2 emissions-savings to a whole year, more than 11'300 tonnes are saved.

Interpretation
The success criterion for this KPI was set at a 5% reduction in emissions. The target value was not only achieved but doubled, although the target value was not set very high when compared to other similar projects.
Reductions in CO_2 emissions are beneficial for the planet and future generations. Significant savings are crucial for Athens and Greece in order to achieve their climate targets. Extrapolating the results to the whole city center up to year 2030, the impact appears to be significant. Athens' target for 2030 is cutting greenhouse gas emissions by 40%, which translates into approx. 2'000'000 tonnes of CO_2. 67'800 tonnes – the rough estimation of CO_2 emissions-savings until 2030 – correspond to 3,4% of 2'000'000 tonnes, proving a substantial reduction.

<u>NO_X-emissions</u>

Impact
The results reveal a reduction in NO_X-emissions by more than 13%. In one typical rush hour, ca. 0,49kg of NO_X emissions are saved. Applying the air pollution cost of NO_X and according to the Handbook on the external costs of transport[5], the emissions avoided are worth €5.1/kg. Extrapolated to a year, this translates into an economic valuation of more than €4'500 in the studied area.

Interpretation
The success criterion for this KPI was set at a 5% reduction in emissions. The target value was not only achieved, but more than doubled.
Reductions in NO_X emissions are beneficial for the local population in terms of better air quality and consequentially better health. This aligns with city and country goals. Greece's national commitment under Directive 2016/2284 is to reduce national NO_X emissions by 31% between 2020 and 2029 (compared to 2005). Since this solution contributes to a 13% reduction, and along with the adoption of some other technical advances and upgrades (e.g., electrification), the impact of the reduction may be considered as significant.

4.1.2.4 Economic KPA

<u>Passengers' costs</u>

Impact
The results reveal a reduction in passenger costs. by more than 11%. In one typical rush hour, almost 500kg of fuel are saved. Assuming an average price of €1,65 per litre fuel, when extrapolated to a year, this translates into yearly cost savings of more than €1.4 million along the studied corridor, and more than €7'000'000 for the Athens city center under the optimistic scenario.

Interpretation
The success criterion of a 5% cost reduction was outperformed and, in fact, doubled.
All road users benefit from the reduced costs. However, the Handbook on the external costs of transport[5] stresses that fuel savings constitute internal cost savings for operators/users and not external cost reductions.
Fuel costs are tangible monetary costs, especially for private vehicles. Therefore, the impact of the respective savings may be considered high. This also includes the risk of a negative feedback effect, leading to an increase in private car journeys. Potential induced effects/incentives must be monitored and reviewed.

In any case, OASA is having a direct financial benefit. As argued above, 25% of the gains are considered to be attributed to OASA. Despite the actual benefit not being quantifiable, the yearly savings are estimated as a seven-figure amount, given also the fact of (the until now) low electric vehicle penetration into the Organization’s fleet.

4.1.2.5 Liability KPA

Impact
The results report an adequate consideration of liability risks. While numerical quantification of liability risk is not possible, results demonstrate that the solution is structured to mitigate potential liability, ensuring operator confidence, regulatory feasibility, and scalability for wider deployment of CCAM technologies. All in all, liability risks are adequately identified and considered for operators, organisations, and manufacturers.

Interpretation
The success criterion for this KPI was identified as the adequate mitigation of liability risks for operators/organisations/manufacturers. Through training, structured workflows, and system alerts, operator and fleet risks are mitigated to acceptable levels, ensuring confidence in deployment.
The stakeholders impacted by liability risks typically span across three levels (in the context of CCAM systems): operators (day-to-day operational use of CCAM systems), organisations (service management and coordination), and manufacturers (product design). Moreover, regulatory bodies are impacted by the framework's compliance with EU regulations, ensuring that PT systems adhere to legal standards.
While no direct monetisation or quantification of liability risk reduction can be performed, the structured approach helps mitigate potential legal risks and supports regulatory compliance, which is crucial for the future adoption of these solutions in other cities and EU-wide deployments. The absence of doubt regarding the existing liability risks enables scalability, since it ensures the readiness of CCAM solutions for wider deployment. This is of upmost importance, since liability issues may pose significant barriers in terms of potential widespread implementation of the CONDUCTOR solutions.

4.1.3 Summary of impacts

<u>Benchmarking</u>

Travel time savings yielded by the CONDUCTOR solutions are significant. This is reflected by the magnitude of >11% travel time reduction, surpassing the EU project benchmark for significant impact. This can be observed in several Horizon / MTM cluster deliverables, relevant to the CONDUCTOR project:

- ORCHESTRA’s[14,15] cooperative traffic management reports travel time reductions of >10%, which are considered “major impact class”.
- TANGENT’s[12,13] Athens Target was to reduce travel times by 10% at peak hours.
- SHOW[16] reports time savings of 5-15% in pilot corridors, which are considered “moderate to high”.

Having an equal and better performance than affiliate projects, while being useful to associated stakeholders, safely leads to the conclusion of the project having an important impact on travel time savings.
Also, the results for passenger waiting time at transfer stops, with a more than 80% improvement or a reduction of almost 10 minutes, outperform these of other projects, since:

- ORCHESTRA[14,15] had only modest improvements of max. -25% in potential waiting time.
- SHOW[16] yielded results, where waiting times do not exceed 10 minutes, with best-case results of 4-6 minutes.

The results for GHG emission reductions seem to be in correspondence with other reference projects' outcomes:

- TANGENT[12,13] reports diverging results between pilot sites, with ca. 10% CO_2 reductions. Significantly higher savings were achieved in TANGENT's Athens pilot, with an achieved improvement of 22.65%.
- ORCHESTRA[14,15] uses a classification of impact levels in order to assess how traffic management improvements (including multimodal management and incident optimisation) affect CO_2 emissions, congestion, and other operational outcomes, with a >10% reduction being considered as "major impact".

Economic Valuation

In summary, the UC1 Athens results indicate a significant improvement in efficiency and sustainability, delivering an overall economic gain of €8'100'000 per year for the studied corridor. When extrapolated to the entire city center of Athens, a potential roll-out could yield an economic valuation of ca. €54'000'000 per year. The economic gains for the studied corridor & feeder line are summed as follows:

- €6.45mio from travel time savings for all users in UC1 scope.
- €0.05mio from improved transfer time savings in PT-feeder lines.
- €1.45mio from fuel savings across all road users in UC1 scope.
- €0.21mio from reductions in greenhouse gas (GHG) emissions in UC1 scope.

It is difficult to quantify the cost for the introduction of the CCAM solutions. According to a wide range of sources and European Intelligent Transportation Systems (ITS) and CCAM project benchmarks, it can be assumed that, for the studied corridor of Alexandras Ave. (14 junctions), the CTMS/C-ITS deployment would reasonably cost between €0.5-3 millions, depending on many factors (sensor, connectivity, integration complexity, etc.).
The financial benefits yielded by the CONDUUCTOR solutions suggest that the annual (external) benefits can offset a large share of the investment within a single year, maybe even shortening the payback period to less than a year with city-wide scaling. This suggests an impressive cost-benefit ratio and strong justification for wider implementation.

Non-monetary impacts

The positive economic assessment is supplemented by non-monetary aspects. The non-monetary impacts are crucial for long-term sustainability and user satisfaction. The main take-aways from the UC1 Athens include:

- Improved ETA accuracy, which enhances user experience and trust, leading to increased ridership and system reliability.
- Incident Management, which strengthens system resilience, ensuring service continuity during disruptions.
- Liability Management, with which the structured approach ensures that liability risks are effectively addressed, contributing to the scalability and future deployment of the system.
- Other Key Impacts that are worth mentioning include the significant reductions in GHG emissions, which contribute to the city's climate goals and support overall environmental sustainability, which most likely even outweighs the monetizable effects that are assigned to the reductions.

Conclusion

In conclusion, the outcomes of UC1 Athens are promising from not only an environmental and economic perspective, but also in terms of operational feasibility and the broad applicability of cooperative traffic management solutions across urban environments. These results offer a robust foundation for scaling the solution and integrating similar strategies in other cities.

4.1.4 Broader impacts of CONDUCTOR-solutions

The impact of UC1 Athens results is relevant to the overall objectives of the CONDUCTOR project. Positive impacts observed in the pilot study, particularly in traffic management optimization, travel time reductions, emissions savings, and system reliability, align directly with the project's goal of creating a scalable and sustainable traffic management framework. By integrating these findings with other CONDUCTOR solution bundles, Athens' success serves as a model for the implementation of CCAM solutions in other urban centers across Europe.

Key aspects include:
- Scalability: The methodological approach used in Athens, which includes integration of PT and advanced traffic management tools, can be expanded to other metropolitan areas facing similar congestion and multimodal transport challenges.
- Regulatory Feasibility: The structured management of liability risks ensures that the CONDUCTOR solution can meet legal requirements and regulations in other cities, paving the way for EU-wide adoption.
- Operational Transferability: The tools and methodologies developed in Athens are transferable to other cities, ensuring that the benefits of multimodal coordination, reduced emissions, and improved travel times can be replicated in different urban environments.

These elements together ensure that the pilot results are not just locally relevant but hold significant potential for broader application within Europe and beyond, contributing to the future of smart city mobility systems.

4.2 Use Case 1 Almelo

A major logistics corridor in Almelo (NL) suffers from truck delays, increased fuel consumption, and local emissions due to frequent signal stops. The rationale behind the Almelo pilot is to improve freight efficiency and reduce the impacts on residents. UC1 Almelo 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.

The results of the Connected Transport Corridors UC1 Almelo are reported in D5.3[3].

4.2.1 UC-specific methodology

Given the pilot's focus on a single road section, albeit one of major relevance for Almelo's heavy-duty vehicle (HDV) traffic, no extrapolation to the entire city network was conducted. Instead, the observed results were contextualized to reflect a realistic level of daily operations:

- Over the six-month pilot period, approximately 1'200 HDV passages from pilot participants were recorded, averaging around 90 passages per intelligent Traffic Light Controller (iTLC) during the same period. This corresponds to roughly 0.5 HDVs per day.
- The overall demand for the studied section, however, is estimated at 2'500-3'000 HDVs per day (around 10% of total traffic) at each intersection.
- This traffic volume serves as the reference for monetising the impacts
- While limited in spatial scope, the studied section captures a highly significant share of Almelo's freight movements and therefore provides a meaningful basis for assessing the system's potential benefits citywide. The environmental and economic impacts were derived using average fuel savings and associated CO_2 and cost reductions per prevented stop, as reported in the results in D5.3[3].

To quantify the impact of the results under an optimistic scenario, it is assumed that all HDV traffic along the corridor is managed by the iTLC system. To avoid overestimating the benefits, conservative (lower-bound) values are applied. Specifically, a reduction of 0.5 kg CO_2 per trip is assumed, with an estimated 2'500 HDV trips per day along the studied section. These figures refer solely to the pilot corridor and presume full adoption by heavy-duty vehicles, lower uptake rates would result in proportionally smaller savings.

4.2.2 KPA-/KPI-Results Almelo

The following sub-chapters report on the KPIs and impacts associated with the collected results for UC1 Almelo.

4.2.2.1 Technical KPA

Traffic signal capacity

Impact
The results reveal no change in the average discharge rate when comparing the scenarios with and without implementation of freight signal priority.

Interpretation
The success criterion for this KPI was defined as a 5% increase in the maximum discharge rate. The target was not achieved.
The optimised traffic signals are targeting specifically HDVs, with truck priority possibly affecting other road users (cars, PT, cyclists) by hindering their movement in favour of HDVs.
Even though the results suggest no overall traffic capacity increases, the findings demonstrate scalability of the conditional signal priority for freight in real-world conditions, supporting transferability to other corridors or cities. Improved progression of freight vehicles and increased

throughput of HDVs along key corridors imply an improvement of operational efficiency. In general, augmented traffic capacities also imply induced demand (growth). As such, they should be examined under this lens too.

Governance Model

Impact
The results reveal that the road authority reflected on the results of the pilot and, on this basis, developed a draft governance model regarding prioritisation. The municipality defined distinct priority levels per user group, embedded the model into its mobility vision, and confirmed plans for permanent and extended deployment.

Interpretation
The success criterion for this KPI was the establishment of a new policy for prioritising specific target groups. Despite the development being at its first stages, the target was achieved.
Besides the associated road users, who the policy regards, other affected stakeholders include the local municipality and the road authority.
Altogether, the impact of the establishment of a new policy is relevant. In Almelo, the institutional feasibility, a decisive factor for further implementation, was additionally assessed.

4.2.2.2 Social KPA

Residents' wellbeing

Impact
The results suggest improvements in residents' wellbeing. The pilot reduced the number of stops and acceleration events for heavy vehicles. While noise and sound power levels were not explicitly measured, the reduction in stop-and-go behaviour implies a reduction in transient engine noise and vibration events, thus qualitatively improving environmental comfort along the freight corridor. For the prioritised vehicles, a reduction of up to 30% in the number of stops (and a 50% reduction in fraction of stops) was reported. Along the major corridor, the number of stops reduces from (on average) 5.1 to 3.6 when using the system. However, when considering overall traffic at intersections, the impact may remain limited. There were no clear effects on the total number of stops: while high-emitting vehicles stopped less frequently, passenger cars often compensated. Still, the results confirm that other traffic was only marginally affected by the freight signal priority. Overall, the findings also show considerable variation across different intersections.

Interpretation
The success criterion for this KPI was set as a 10% reduction in stops. This was clearly achieved (albeit only for the prioritised vehicles).
Besides the positive impacts for truck drivers, local residents benefit too. Less engine idling translates into lower air pollution exposure. Less acceleration/braking implies lower noise exposure for nearby residents. All types of emissions are reduced.
In total, even though the number of stops for the overall traffic are reduced less strongly, the reduction of stops for HDVs is deemed as significantly beneficial. Fewer stops of trucks allow for a smoother traffic flow and ultimately reduced noise peaks for residents. While sound power levels per vehicle or total noise emitted were not directly measured, the reduction in stop-and-go behaviour serves as a proxy indicator for lower acoustic impact, hence a positive impact.

Road safety

Impact
The results reveal no change in road safety due to red-light negations. The project results report no observed no evidence of any change (0%), i.e., no difference in red-light negations. The reduction of stops for heavy vehicles (ca. -30%) and the smoother traffic progression decrease the likelihood

of late braking, red-light running, and rear-end collisions. The municipality highlights these results as safety benefits of the freight signal priority system, while no adverse impacts were reported for other road users.

Interpretation
No success criteria were defined for this KPI. The benefits of improved road safety mainly regard road users.
Overall, no significant changes in terms of fewer red light violations were reported. Smoother traffic flow is considered beneficial as it leads to greater road safety, but the results of the UC1 Almelo pilot project cannot be considered significantly effective in terms of road safety.

4.2.2.3 Environmental KPA

GHG emission reductions

Impact
The results reveal a reduction in GHG emissions. The number of stops of HDVs / trucks along the major corridor changed from, an average of 5.1 to 3.6. It can be assumed that each stop costs about 0.32-0.40kg CO_2, implying a reduction of 0.5kg CO_2 when traveling along the corridor. Although NO_x and noise were not directly quantified, reduced acceleration and idling are expected to further reduce local pollutants and enhance air quality along the corridor. In one day, 1’250 tonnes of CO_2 emissions can be saved. Applying the climate change avoidance costs of €100/tonne for CO_2, extrapolated to a year (>450 tonnes saved), this translates into avoidance costs of more than €45’000 for the studied corridor
A question that remains pending regards the exhausted emissions from all road users, since an increase in stops by other traffic, despite implying a non-existent reduction in the total number of stops, it can still (possibly) derive environmental benefits, since private vehicle emissions are less than those exhausted by HDVs. The results confirm a net benefit.

Interpretation
The success criterion for this KPI was set as a 5% reduction in emissions. Despite results for the overall emissions not being available, the examined emissions for halting in stop-and-go situations were reduced by almost 30%.
Reductions in CO_2 emissions are beneficial for environment and future generations. Significant savings are particularly crucial for Almelo and the Netherlands in order to achieve their climate targets.
The savings are also important for the logistics sector and for the specific corridor in particular. However, further measures must be employed in order to reduce the overall GHG emissions.

Air quality improvements

Impact
The results reveal tangible improvements in air quality due to reduced fuel consumption. By lowering the average number of truck stops from 5.1 to 3.6 per trip, the solution contributes to fuel savings. Since each stop costs about 0.12 liters of fuel, the reduction of stops allows for a drop in fuel consumption from 0.612 liters of diesel to 0.432 liters of diesel when traveling along the corridor. These reductions translate into lower exhaust, particulate matter, and NO_x emissions along the freight corridors, directly contributing to improved local air quality and supporting the municipality’s environmental objectives.

Interpretation
The success criterion targeted a reduction in fuel consumption by 5%. In the case of HDV’s stop-reduction, the success criterion was met.
Improved air quality mainly benefits the local population. Fuel savings for HDVs benefit the logistics operators, by reducing their operational costs.

Noise pollution/emission reductions

Impact
The exact noise emissions were not specified in the results. Instead, reference is made to proxies in the form of the number of stops from HDVs. The results are reported previously under GHG emission reductions.

4.2.2.4 Economic KPA

Fuel consumption

Impact
The results and impacts regarding fuel consumption reductions are treated above, in the air quality improvement KPI, by making reference to the number of stops of HDVs.
Assuming an optimistic scenario (full adoption by HDVs on the studied corridor), applying the in D5.3[3] suggested fuel prices of €1.53 per litre, daily fuel savings of 450 litres translate into ca. 700€. Accordingly, the Almelo pilot could save roughly €250’000 annually, in fuel costs.

Service reliability

Impact
No direct results were reported for this KPI. However, the pilot demonstrated shorter and more consistent travel times for freight vehicles. Though travel-time percentiles were not explicitly reported, the reduction in average waiting time (-20%) and number of stops (-30%) directly translates into improved travel-time reliability and a narrower variance between average and 95th percentile trips.

Interpretation
The success criterion targeted a 5% decrease in travel time. It is assumed that the goal was achieved, despite the absence of direct evidence. Improved service reliability benefits different stakeholders. Mainly, freight operators and logistics companies aspire to shorter, more predictable trip times. Truck drivers gain benefits from improved driving comfort and predictability.
Nowadays, just-in-time deliveries are becoming increasingly crucial, with service reliability constituting a significant contributing factor in this direction.

Efficiency (delays)

Impact
The results suggest increased efficiency, with less delays. The efficiency of logistics services improved by reducing intersection delays for heavy vehicles. Also, the waiting time of the first vehicle in queue can be used as a reliable proxy for truck delay. Results show that this waiting time decreased by 20-40% on average, exceeding 50% under high-priority settings. This directly reflects a reduction in additional travel time compared to an uninterrupted pass, confirming that the solution substantially improves the efficiency and reliability of logistic services.

Interpretation
The success criterion targeted a 5% decrease in delay, with the target being presumably achieved. Once again, the benefitting stakeholders are the ones mainly involved in logistics operations at all stages.
Consideration of the limitations in the findings, the efficiency gains and delay reductions are deemed significant.

4.2.2.5 Human Performance KPA

<u>Consistency of human role</u>

Impact
The results suggest positive outcomes with respect to the application being consistent with human capabilities and limitations. Participants confirm that messages by the application can be easily comprehended and complied with. Three main weaknesses were mentioned: lack of reliability, poor integration, and the potential to increase waiting times for other vehicles.

Interpretation
The success criteria involved receiving positive feedback from participants and stakeholders, with the objective deemed successful.
The main beneficiaries are truck drivers, who could perform their tasks safely and efficiently without facing additional cognitive or operational burdens, even when interacting with new digital tools. Fleet and logistics managers also benefit from the system's predictability and the absence of new human-factor risks, which supports smoother coordination and safer fleet operations. Traffic managers gain assurance that system procedures and role boundaries are well defined, limiting human-error propagation within signal-control operations.
Technically, the system demonstrates reliable human-machine consistency. Overall, the solution preserved a clear, human-centred task distribution and increased confidence among all operational stakeholders, demonstrating that the system aligns with real-world human performance capacities.

<u>Technical system's support</u>

Impact
Participants confirm that the system supported them in reducing delays and travel times.

Interpretation
The success criteria involved receiving positive feedback from participants and stakeholders, with the objective deemed successful.
The affected stakeholders with respect to human performance issues are mainly the truck drivers.
Technically, the system demonstrates reliable human-machine consistency. The solution effectively supports operator tasks by enabling smoother, more predictable driving and clear system responses. Although integration with onboard devices remains partial, all technical risks were identified and remain within acceptable limits. Overall, the system maintains functional reliability, supports operator performance, and aligns well with human capabilities.

4.2.2.6 Liability KPA

Impact
The results reveal that liability risks were adequately identified and considered.

Interpretation
The success criterion was defined as an adequate mitigation of liability risks . The target was achieved.
The main beneficiaries are traffic managers / road authorities, who benefit from operational and organisational accountability.
Governance and regulatory feasibility ensure scalability as well as operator acceptance.

4.2.3 Summary of impacts

Benchmarking

The overall impact of GHG emission reductions cannot be estimated. It can be assumed, that it surpasses a rate of 5-10%. This result is slightly inferior to the ones from comparable reference projects from the Horizon / MTM cluster:

- TANGENT[12,13] reports diverging results between pilot sites, with an average of 10% reduction in CO_2 emissions. Significantly higher savings were achieved in TANGENT's Athens pilot of about 22.65%.
- ORCHESTRA[14,15] uses a classification of impact levels to assess how traffic management improvements (including multimodal management and incident optimisation) affect CO_2 emissions, congestion, and other operational outcomes, with a rate of >10% considered as "major impact".

Benchmarking the results on service reliability against other reference projects, the 20-30% improvement in waiting time and stops seem expected:

- ORCHESTRA[14,15] implemented Connected and Autonomous Vehicle (CAV) platooning and a collaborative appointment system, that reduced waiting times for trucks at gates. This yielded a reduction in average waiting time of up to 25% during high-demand periods.

A similar project was conducted in the Netherlands, in the city of Helmond, where a Traffic Light Prioritization was implemented. The reference values for fuel savings suggest that the impacts in Almelo may be underestimated:

- Transport Technology Forum – Insights from Helmond[18] report (besides increases in comfort and air quality) fuel savings of up to 1 liter per avoided stop.

Economic Valuation

Overall, the economic gain under UC1 Almelo's scope cannot be comprehensively quantified. Under an optimistic scenario, the combined economic valuation of fuel savings and CO_2 emissions reductions equal to ca. €300'000 per year for only the studied corridor. However, the contributing factors to these gains are analysed as follows:

- €250'000 from fuel savings for HDVs.
- €45'000 from reductions in CO_2.
- Efficiency/Delays (waiting time by 20-40% on average, >50% under high-priority conditions)
- Service Reliability (improved travel-time reliability, reduced average waiting time (-20%) and stops (-30%) for HDVs)
- Air Quality (ca. -30%)

All in all, a qualitative valuation infers a medium economic impact, primarily driven by improved freight efficiency, reduced delays, and fuel savings. The benefits accrue mainly to logistics operators and truck drivers through lower operating costs and more predictable travel times, with secondary advantages for the municipality and residents through reduced emissions and improved environmental conditions along the corridor.

While specific investment figures for the conditional freight priority system are not disclosed, the scale of delay and fuel reductions suggests that the solution might achieve a positive cost-benefit balance in the long term. Benchmarking against comparable C-ITS freight corridor deployments indicates that similar implementations typically require investments of around €150'000-€300'000. This comes from typical cost brackets for small-scale C-ITS or cooperative freight corridor pilots. Derived from the Handbook on the External Costs of Transport[5] for valuing fuel/time savings, annual operational savings of 10-20% are roughly expectable. Estimating the payback period is only possible very approximately and is therefore abstained from here, due to too high uncertainties.

Non-monetary impacts

The economically monetizable impacts are supplemented by non-monetary aspects. Some of them might be even more impactful than just the economic valuation. The main take-aways from the UC1 Almelo include:

- Governance and Institutional Feasibility
  - The establishment of a governance model for signal priority and the municipality's decision to include it in Almelo's mobility vision demonstrate strong institutional readiness, confirming regulatory feasibility and governance maturity.
- Road Smoothness and Safety
  - Smoother progression of HDVs reduces the likelihood of late braking, rear-end collisions, and unsafe acceleration.
- Human-Machine Integration
  - Positive feedback from drivers confirms high usability and low cognitive workload, showing that the system integrates smoothly into daily operations.

Conclusion

In conclusion, the outcomes of UC1 Almelo are promising not only from an operational perspective but also in terms of institutional readiness and scalability. The pilot demonstrates that conditional signal priority can effectively enhance freight efficiency, reduce delays, and improve local air quality without compromising safety or overall network performance. The establishment of a governance framework and strong user acceptance further confirm the feasibility of extending the solution to other logistics corridors. Altogether, UC1 Almelo provides a solid foundation for integrating C-ITS freight management solutions into broader smart mobility strategies across Europe.

4.2.4 Broader impacts of CONDUCTOR-solutions

The impact of UC1 Almelo results is closely aligned with the overarching objectives of the CONDUCTOR project. The demonstrated improvements in freight efficiency, operational reliability, and environmental performance contribute directly to the project's ambition of fostering scalable, cooperative, and sustainable mobility management frameworks. By integrating conditional signal priority for HDVs along a major logistics corridor, UC1 Almelo illustrates how data-driven traffic management can enhance both economic efficiency and urban livability.

Key aspects include:

- Scalability: The freight-priority concept and system architecture tested in Almelo can be scaled to other regional or trans-European logistics corridors, supporting broader applications of cooperative traffic management for freight.
- Governance and Policy Integration: The establishment of a governance model and its incorporation into Almelo's mobility vision confirm institutional readiness and provide a policy blueprint for other municipalities aiming to balance freight flows with urban sustainability goals.
- Operational Transferability: The demonstrated compatibility with existing traffic management systems ensures that similar deployments can be integrated with limited adaptation, facilitating replication across cities and regions.

Together, these elements confirm that UC1 Almelo not only generates local efficiency and environmental benefits but also contributes to the wider CONDUCTOR goal of advancing cooperative, low-emission freight mobility across Europe.

4.3 Use Case 1 Madrid

Madrid's M-30 ring road and adjacent network face recurrent congestion from accidents, weather, or planned works. Recovery from such disruptions is slow. The challenge is to integrate Connected & Automated Vehicles (CAVs) into traffic management to accelerate recovery under mixed fleet conditions. The UC1 Madrid considered traffic management solutions to accelerate network recovery after planned and unplanned events in the context of transition towards a traffic composition with larger shares of connected and automated vehicles that can communicate with their surroundings and with a traffic management centre directly. The UC1 Madrid investigated strategies for planned and unplanned events to restore optimal transport network operations.

The results of UC1 Madrid are extensively reported in D5.3[3].

4.3.1 UC-specific methodology

For UC1 Madrid, different scenarios were tested:
- Planned scenario: planned event on the network, where congestion mitigation strategies were tested. The traffic demand consisted of mixed traffic involving Connected Vehicles (CVs) as well as conventional vehicles.
- Unplanned scenario: sudden event on the network, where congestion mitigation strategies were tested similarly to the planned event scenario.

Also, different vehicle mixes were simulated for the different Validation Exercises:
- 25% CVs (& 75% conventional cars), and
- 45% CVs (& 55% conventional cars).

These can be interpreted as the different scenarios (conservative & ambitious). The results identified the optimal penetration rate for UC1 Madrid at around 45% CV. Therefore, the main focus lays on the 45% penetration scenario.
It should also be noted that the solution proposed alternative routes for CVs in the event of incidents. However, these routes were not dynamically calculated but rather pre-defined. As a result, penetration rates above 45% did not necessarily lead to better outcomes, since all CVs were redirected along the same routes, which in turn became congested.

The analysis covers the morning peak period (7:00-9:00AM) for both planned and unplanned event scenarios, when the overall network accommodates a total of 695'663 trips.

4.3.2 KPA-/KPI-Results Madrid

The following sub-chapters report on the KPIs and impacts associated with the collected results.

4.3.2.1 Technical KPA

<u>Travel time</u>

Impact
The results indicate a notable decrease in travel times as CV penetration increases, across both planned and unplanned events. The average travel time for planned / unplanned scenarios dropped from 108.3 / 105.38 sec/km to 102.5 / 100.22 sec/km (45% CV penetration) respectively. More specifically, it decreased by 4-5% for CVs and by 2-3% for conventional vehicles, compared with the baseline scenario (0% CV penetration).

Interpretation
The success criteria targeted an increase of average mean speeds, with the shorter travel times confirming the increase.

Affected stakeholders include all road users, with a special benefit to CVs. Additionally, transport and traffic authorities (Madrid city council, Calle 30, Consorcio Regional de Transportes de Madrid) benefit from reduced congestion and improved travel efficiency.
Although the simulated improvement refers to a single type of event and a localized work-zone scenario, the results demonstrate network-level benefits that scale beyond the directly impacted area. A 4-5% reduction in average travel time across the entire network indicates that the positive effects of CV coordination enhance overall flow efficiency and reduce delays even for uninvolved trips. Hence, even though the intervention addresses a localized problem, the observed network-wide efficiency gains justify the classification of the impact of travel-time savings as significant.

Network recovery time reduction

Impact
The results indicate improvements in network recovery time. The traffic management solution significantly improved network recovery after both planned and unplanned events. The mean queue lengths in the network decreased by up to 15%. For planned / unplanned scenarios, queues shrunk from 41’340 / 35’550 vehicles (baseline) to 35’097 / 31’339 vehicles (45% CV penetration).

Interpretation
The success criteria targeted a decrease of traffic queues by 10-20%. Queue lengths for both planned and unplanned scenarios shrunk by more than 10%, with the target achieved.
All road users benefit from the results. Faster recovery times translate into shorter travel times. In addition, the afore-mentioned transport and traffic authorities benefit from faster network recoveries, and, hence, improved travel efficiency.
The impact can be considered significant. The positive effects on an individual event yield network-level benefit. A more widespread application that scales beyond the directly impacted area would have increasing impacts. Generally, the traffic management solution could be a key contributor for alleviating bottlenecks and avoiding long network recovery times.

4.3.2.2 Social KPA

Improved travel time & delays

Impact
The results indicate decreases in travel times, with specific results reported in 4.3.2.1.
In the Social KPA design, this KPI was planned to be validated through stakeholder feedback. While the numerical evidence confirms reductions in total travel time and delays, there is no stakeholder feedback to be reported.
The total travel time of all vehicles in the network estimated a value of 93’592 hours for the planned scenario (0% CV penetration), which dropped to 91’588 hours under 45% CV penetration. Instead, in the unplanned scenario, the total travel time increased from 106’043 hours to 110’494 hours respectively. It should be noted, however, that these figures refer to the overall morning peak network (695’663 trips) rather than solely to the incident-affected area.

Interpretation
The success criteria for this KPI involved receiving positive stakeholder feedback, which did not take place.
Total travel time reduced by 2% in the planned scenario, while it increased by 2% in the unplanned scenario due to vehicles being redirected to longer routes. The impacts on the overall network seem to be negligible.

4.3.2.3 Environmental KPA

GHG emission reductions

Impact
The results do not indicate GHG emission reductions. The network maintained stable greenhouse gas emissions across all tested scenarios. In the planned event simulation, total CO_2 emissions changed by only +0.006% compared to the baseline. Emissions and total energy consumption are almost not affected, compared to the baseline scenario, due to a solution limitation considering the impact of rerouting only at a network level.

Interpretation
The success criterion was to 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. The target is achieved.
Since there are no notable changes, no stakeholders are impacted.
The results confirm that connected-vehicle coordination improved traffic efficiency without increasing the environmental impact. Overall, the system demonstrated environmental neutrality, showing that reductions in congestion and delays did not translate into measurable GHG emission increases.

4.3.2.4 Economic KPA

Delays

Impact
The delay time for planned / unplanned scenarios decreased from 40.2 / 37.23 sec/km (0% CV penetration) to 34.68 / 32.29 sec/km (45% CV). Average delays dropped by 15% for CVs and by 12% for conventional vehicles in the planned event, and by 10% for CVs and 8% for conventional vehicles in the unplanned event. The optimal effect was observed at 45% CV penetration, where the system achieved the most balanced improvement between delay reduction and stable traffic flow.

Interpretation
The success criterion was supposed to be assessed by reference to the total travel delays, with the respective economic impact derived in this manner. Since the total delay decreased, the objective is deemed successful.
All road users benefit from the reduction in delays, with improvement in transport system efficiency affecting all involved parties.
In both events, connected vehicles systematically show lower average delays than conventional ones, demonstrating the impactful effectiveness of cooperative rerouting and priority mechanisms.

4.3.2.5 Human Performance KPA

Consistency of human role

Impact
The results reveal that human performance risks were adequately identified and considered. Stakeholders confirmed that no new human-performance risks were introduced and that potential operator limitations were adequately taken into account.

Interpretation
The success criterion for this KPI involved receiving positive feedback from stakeholders on whether human performance risks for operators are adequately identified and considered. The target was achieved.

The main stakeholders benefiting are truck drivers, who experienced smoother driving conditions and no additional operational burden, and logistics operators, who benefited from clearer, safer task execution within normal cognitive limits.
The solution maintained the consistency of the human role by aligning system functions with user abilities. Human-performance risks were adequately identified and considered, and, most importantly, no new risks were introduced.

Technical system’s support

Impact
Overall, stakeholders agreed that technical risks for operators were adequately identified and considered. The assessment shows that the technical system provided effective functional support to operators (mainly truck drivers and logistics coordinators) in completing their tasks. The system and accompanying smartphone application enhanced operational awareness at intersections and facilitated smoother driving by reducing unnecessary stops. The shortcomings were identified during the pilot, and corresponding technical risks were adequately considered within the project’s human-performance framework. Stakeholders confirmed that, while the system required initial familiarisation, it remained manageable and aligned with user skills.

Interpretation
The success criterion for this KPI involved receiving positive feedback from stakeholders. The target was achieved.
The main stakeholders benefiting are truck drivers, who get additional systems’ support.
The technical system successfully supported operators in performing their tasks by facilitating smoother and more efficient vehicle operation. All technical risks affecting operators, such as reliability issues, feedback absence, and limited integration, were identified, assessed, and deemed acceptable. The overall human-system interface was found to be fit for purpose, with improvements suggested for full integration into onboard systems to reduce manual intervention and cognitive effort.

4.3.2.6 Liability KPA

Impact
The results reveal that liability risks were adequately identified and considered. The analysis compared the current ‘as-is’ operational environment and a future scenario integrating CAVs. Results show that, while liability risks for Traffic Managers and Fleet Managers are currently low, they increase moderately with CAV integration due to new active tasks influencing automated traffic and rerouting decisions. These may lead to indirect or corporate liability (e.g., inadequate procedures or training) or product liability (e.g., data unreliability, design flaws). However, all potential liability profiles were explicitly identified, categorised, and considered, including dependencies between organisational, systemic, and manufacturing risks, and were deemed acceptable with proper mitigation through training, clear procedures, and system documentation.

Interpretation
The success criterion for this KPI was defined as adequate mitigation of liability risks. The target was achieved.
Mainly impacted stakeholders comprise traffic managers / road authorities from Almelo, but also fleet managers / logistics operators, for reduced organisational and operational liability or lower corporate liability and increased legal certainty respectively.
The UC1 Almelo pilot demonstrated that all foreseeable liability risks for operators, organisations, and manufacturers were recognised, categorised, and controlled through preventive governance. While future CAV integration could introduce moderate new exposures, these are manageable within existing legal and organisational frameworks. All this combined, paves the way for further uptake of the CONDUCTOR solutions, beyond the Almelo-corridor.

4.3.3 Summary of impacts

Benchmarking

At first, the results on travel times seem moderate. Decreases of 4-5% for CVs and of 2-3% for conventional vehicles do not live up to high expectations:

- ORCHESTRA's[14,15] cooperative traffic management reports travel time reductions of >10%, which are considered "major impact class".
- SHOW[16] reports time savings of 5-15% in pilot corridors, which are considered "moderate to high".

It must be noted though, that these savings refer to the intervention area only, while the rest of the network is not considered.

On the other hand, the results of UC1 Madrid resonate with the typically suggested outcomes from Aimsun. UC1 Madrid results lie close to the outcomes that Aimsun typically promises for incident-centric, network-scale management: faster recovery and less congestion. Results of ca. 15% shorter queues and network-wide drops in average travel time during planned/unplanned events map onto Aimsun Live's pitch of rapid prediction and strategy selection to mitigate incident impacts on corridors like the M-30. As for the emissions' neutrality result, this aligns with Aimsun's tooling (LEM in Aimsun Next) and with expectations when interventions primarily reroute traffic rather than change speed/acceleration profiles (i.e., efficiency gains without environmental downside).

Economic Valuation

Overall, the economic gain under UC1 Madrid's scope cannot be precisely quantified. However, the contributing factors to these economic gains are the following:

- Travel Time Improvements (ca. 4-5% reduction for CAVs; 2-3% for conventional vehicles)
- Delay Reductions (8-17% reduction)
- Emission Reductions (proportionally to reduced travel times and smoother network operation)

All in all, a qualitative valuation infers a medium economic impact, primarily driven by improved network efficiency, reduced delays, and emission savings. The benefits accrue mainly to road users and the road authority, through shorter travel times, enhanced network recovery, and lower operational costs related to congestion and fuel consumption. Secondary advantages arise for the municipality and the residents, through reduced environmental impacts and improved traffic reliability across the metropolitan area.

While specific investment figures for the CAV-enabled traffic management system are not disclosed, the magnitude of network-level time and emission savings suggests that the solution would achieve a positive cost-benefit balance when deployed at a larger scale. The big unknown factor in the equation are CAVs. The uptake of CAVs depends to a large extent on private users. And the impact's magnitude depends on a (as high as possible) penetration rate of CAVs.

Non-monetary impacts

The monetizable impacts of UC1 Madrid are complemented by a series of non-monetary outcomes that are equally relevant for long-term system resilience, safety, and governance. The main take-aways from the Madrid UC1 include:

- System Resilience and Network Recovery
    - The pilot demonstrated that integrating CAVs into traffic management can significantly accelerate network recovery after both planned and unplanned disruptions. This enhances the robustness of the transport system and ensures faster return to stable operations, improving overall traffic reliability.
- Human–Machine Coordination

    - Operators and traffic managers reported that automated decision-support tools improved their situational awareness and reduced cognitive workload. The system provided timely and transparent information, ensuring that humans remained in control while benefiting from enhanced analytical support.
- Governance and Organisational Readiness
    - The pilot fostered stronger collaboration between city authorities, road operators, and technology providers. The involvement of Madrid Calle 30 and the Regional Transport Consortium demonstrated that cooperative traffic management can be embedded within existing governance structures, ensuring feasibility and acceptance for future deployment.

<u>Conclusion</u>

In conclusion, the outcomes of UC1 Madrid are promising, especially also in terms of network resilience and operational scalability. The pilot demonstrates that integrating connected and automated vehicles into traffic management can effectively reduce delays, improve network recovery, and enhance overall traffic efficiency without negative side effects on emissions. The strong collaboration between city authorities, operators, and technology partners confirms the institutional feasibility of such cooperative systems. Altogether, UC1 Madrid provides a strong foundation for extending CAV-enabled traffic management to other metropolitan areas, supporting the broader transition toward data-driven and resilient urban mobility networks across Europe.
The observation that penetration rates above 45% of CVs resulted in negative impacts should not be seen as a major concern. As explained earlier in the introduction (4.3.1), the alternative routes were pre-defined rather than dynamically generated. This limitation could be addressed by refining the routing algorithms, for instance, by incorporating adaptive logic or AI-based optimisation to better distribute traffic in real time.

4.3.4 Broader impacts of CONDUCTOR-solutions

The impact of UC1 Madrid results is strongly aligned with the overarching objectives of the CONDUCTOR project. The demonstrated reductions in travel time, network delays, and emissions directly contribute to the project's aim of developing scalable, cooperative, and automated traffic management frameworks that improve network efficiency and sustainability. By applying CAV-enabled management strategies to Madrid's M-30 corridor, the pilot illustrates how cooperative systems can enhance resilience in complex urban networks.

Key aspects include:
- Scalability: The tested CAV-integrated traffic management approach can be extended from the M-30 corridor to other metropolitan networks, supporting broader deployment of predictive and cooperative control strategies across large urban areas.
- Operational Transferability: The methodological setup (linking simulation, real-time data, and automated decision support) is transferable to other cities aiming to optimise network recovery and manage mixed traffic fleets.
- Governance and Institutional Integration: The active involvement of Madrid Calle 30, the Regional Transport Consortium, and technology partners confirms the institutional feasibility of implementing cooperative management frameworks within existing governance structures.
- Regulatory and Technological Readiness: The pilot demonstrates interoperability between conventional and automated vehicles and compliance with EU safety and data-governance requirements, strengthening the foundation for larger-scale CCAM adoption.

Together, these elements confirm that UC1 Madrid not only delivers local operational and environmental benefits but also provides valuable evidence for replicating cooperative and automated traffic management solutions across Europe's metropolitan regions, thereby advancing the broader CONDUCTOR vision of efficient, resilient, and low-emission mobility systems.

Use Case 2 Slovenia

The UC2 (Slovenia) deals with the long-term optimisation and continuous refinement of route plans for DRT services in the context of shuttle operations. Overall, it can be said that Slovenia has a rather poor flight connectivity from its international airport. Therefore, passengers need to use the nearby airports in Italy, Croatia or Austria. Due to limited infrastructure supply for that (train, bus), passengers need to utilise the DRT service.
Cross-border shuttle services between Slovenian cities and foreign airports face fluctuating demand, inefficient fixed schedules, and high operational costs. The challenge is to optimise DRT dynamically for passenger satisfaction and sustainability.

The results of UC2 are extensively reported in D5.3[3].

4.3.5 KPA-/KPI-Results Slovenia

The following sub-chapters report on the KPIs and impacts associated with the collected results.

4.3.5.1 Technical KPA

<u>Human intervention optimisation</u>

Impact
The results reveal a strong reduction in the manual intervention rate. The upgraded Demand Responsive Platform (DRP) successfully automated key planning operations, reducing the number of manual interventions required by planners from 13 to 4 actions.

Interpretation
The success criterion was set at a 50% reduction of manual actions per planner. The actualised reduction of roughly 70% (relative to the baseline conditions) fulfils the technical KPI target.
The impacted stakeholders are mainly planners / dispatchers, who experience lower workloads. Also, operations/fleet managers benefit from more predictable planning cycles and the possibility to reallocate planner time to incident response and service quality. Lastly, passengers/customers also benefit from fewer schedule changes and better user experiences (e.g., for enabled late bookings), leading to improved user satisfaction.
As a result, human workload in route planning is significantly improved, enhancing operational scalability and efficiency. This results in a reduction in manual workload for GoOpti planners, as well as in faster and more consistent daily route generation. The above implies a higher scalability potential, as the system can handle more plans with the same or fewer staff. Overall, the results are impactful, with measurable operational, economic, and user-experience benefits. Importantly, these efficiency gains were achieved without increasing staff salaries or hiring additional personnel. Existing planners can now dedicate more time to strategic tasks such as monitoring service quality or supporting GoOpti's expansion into new markets, demonstrating that automation strengthens both productivity and organizational capacity.

<u>Route planning optimisation</u>

Impact
The validation results confirm that the upgraded DRP effectively optimises route plans, with reduced travelled distance through grouping of trips. After implementing trip grouping, an average reduction of about 8% in travelled distance was achieved. Specifically, the baseline value of ca. 84'200km was reduced to ca. 77'406km.

Interpretation
The success criterion for this KPI was set at 3 km less per plan for passenger custom addresses. The optimised plans saved roughly 6’755km of total fleet distance per daily plan, or about 28 km per vehicle per plan (on average). Accordingly, the success target is achieved.
The main beneficiaries include the fleet and operations managers, who gain direct efficiency and cost advantages, the drivers, who experience shorter, more predictable routes, and the passengers, who benefit through shorter routes, improved punctuality and service stability.
Technical efficiency leads to reduced travel distance, hence, lower energy use and lower costs. Overall, the results demonstrate a clear positive impact on route optimisation. The system reduced total fleet distance and the optimisation proved technically robust and operationally effective across varying seasonal scenarios, delivering measurable energy and cost savings while maintaining service reliability, a clear advance for GoOpti.

4.3.5.2 Social KPA

Accessibility improvements

Impact
The results reveal accessibility improvements. An incoming order between 22:00 and 7:00 can be automatically processed and added to a plan (without the need for full replanning). Previously, nightly orders were rejected.

Interpretation
The success criterion for this KPI was set at an 100% increase in bookings between 22:00 and 7:00 for travels during 22:00 and 9:00. The target was achieved.
Three are the main beneficiaries of the results: passengers gain accessibility, fleet managers gain efficiency and revenue stability, and planners gain relief from manual night shifts. This makes this KPI central to both service inclusivity and operational sustainability.
The implementation of the continuous mode improved system accessibility significantly, eliminated rejection of night-time requests, and enhanced both operational efficiency and user experience. Technical performance proved reliable, user satisfaction increased, and governance remained stable and compliant. The results contribute positively to the social and operational impact.

4.3.5.3 Environmental KPA

GHG emission reductions

Impact
The results reveal reductions in GHG emission. The KPI – depicted as a proxy for GHG emissions – was fuel consumption per passenger dropped off and resulted in an 8% reduction. The increase of passengers per shuttle resulted in a decrease in the fuel consumption per passenger, thus contributing to fulfilment of the KPI.

Interpretation
The success criterion for this KPI was set at 5% lesser fuel consumption (l/100km) per passenger. The target value is achieved.
The model primarily benefits GoOpti, as a fleet and operation manager, through the lower fuel consumptions. Moreover, the results prove environmental benefits through reductions in CO_2 emissions. The validation confirms that the upgraded DRP contributes meaningfully to GHG emission reductions through improved routing efficiency and higher vehicle occupancy. This translates directly into reduced CO_2 and NO_x emissions, consistent with moderate-to-major impact classifications in comparable projects. The results demonstrate that environmental benefits emerge as a by-product of technical optimisation, rather than requiring additional operational effort.

4.3.5.4 Economic KPA

Fuel consumption reduction

Impact
The results reveal reduced fuel consumption, achieved through increased occupancy and less kilometers per plan. More specifically, a reduction of 8.8% is observed when comparing the cost of €23.4/passenger before trip grouping implementation and the cost of 21,5€/passenger after the model application.

Interpretation
The success criterion for this KPI targeted a 5% less average cost per kilometres per passenger. The target value is achieved.
All road users benefit from the reduced costs. The Handbook on the external costs of transport[5] stresses that fuel savings are considered as internal cost savings for operators/users, and do not constitute external cost reductions. For DRT operators (i.e., GoOpti), cost savings have a direct impact on the company's profits, and are, thus, of significant importance.

Operational cost reductions

Impact
The results reveal reductions in operational costs. With less manual interactions, planners spend less time to prepare and review plans. Under the CONDUCTOR solution, the planner is mostly just reviewing plans. Planning costs reportedly dropped from €252 to €140 per plan, thanks to a reduction in manual planning hours from 18 to 10 hours per daily plan. After implementation of the model, the required number of hours for plan preparation dropped, with a respective cost reduction of ca. 45%.

Interpretation
The success criterion for this KPI was set at 50% less average planning costs. The objective was met.
The model provides substantial benefits for GoOpti, as the fleet and operations manager, due to lower payroll costs.
This is accompanied by a greater introduction of automation into the whole process, which increases technical efficiency. Apart from the significant financial and technical performance impact, investment costs should also be considered.

Enablement of new service

Impact
The results reveal the enablement of a new service. Three services were added to the production (GoOpti Tracking, Continuous Mode, Optimisation engine), while five services were tested (Continuous planning, Demand Prediction, Traffic Events, Traffic Events Assessment, GoOpti Tracking). The continuous mode enables last minutes product sales.

Interpretation
The success criterion for this KPI was set for four new services tested and two- new services used in production. The objective was met. At the time of the first Validation Exercise, only the Plan Optimisation service had been deployed in production, leading partners to record the KPI as "partially fulfilled" (1 out of 2 deployed; 1 out of 4 tested). Subsequent exercises expanded the validation scope to include Continuous Mode, Continuous Planning, GoOpti Tracking, Traffic Events, and Demand Prediction. By the end of Exercise #3, five new services had been tested and three were operational or production-ready, thereby exceeding the project's success criterion.
The model benefits directly fleet managers through the addition of new services. Continuous Mode and Plan Optimisation reduce manual work. Additionally, this enables new revenue streams (last-minute product sales). Eventually, passengers / end users benefit too, since they gain access to 24/7

booking and last-minute travel options. The continuous integration of night-time and late orders increases accessibility and flexibility.

4.3.5.5 Human Performance KPA

Consistency of human role

Impact
The results confirm that the human role is consistent with human capabilities and limitations. Participants confirm that messages by the application can be easily comprehended and complied with. Planners experience lower workload and fewer manual interventions while maintaining oversight and situational awareness. The system complements human expertise rather than replacing it, preserving control and trust. Average ratings regarding workload, task efficiency, and situational awareness confirm strong usability and acceptance.

Interpretation
The success criterion for this KPI involved receiving positive feedback from stakeholders on whether human performance risks for operators are adequately identified and considered. The target was achieved.
The main affected stakeholders from human performance issues would be the operators.
The KPI on consistency of the human role is fulfilled, with the residual requirement for training considered normal during the adoption of advanced automation tools.

Technical system's support

Impact
The results reveal that the system supports human performance. Participants confirm that the system supported them in reducing delays and travel times. The responses show a high level of perceived technical support. The results demonstrate that the technical systems provide strong support to human operators in their daily tasks. Operators perceive the technology as a facilitative tool that simplifies routine work while maintaining human oversight and decision authority. Technical dependencies on external data are acknowledged but do not compromise the overall system performance.

Interpretation
The success criterion for this KPI involved receiving positive feedback from stakeholders on whether human performance risks for operators are adequately identified and considered. The target was achieved.
Operators emphasize that they can focus on monitoring, communication, and quality assurance, while the system performs background optimization, confirming the positive synergy between human expertise and automated optimisation.

4.3.5.6 Liability KPA

Impact
The results reveal that liability risks were adequately identified and considered. The analysis identified no new liability exposures arising from the upgraded DRP in its current deployment. The system's functions (automated planning, continuous optimisation, and real-time tracking) remain fully under human supervision and within existing contractual and regulatory frameworks.

Interpretation
The success criterion for this KPI was defined as adequate mitigation of liability risks. The target was achieved.

Stakeholders impacted by liability risks span across three levels in the context of CCAM systems: operators, organisations, and manufacturers. Moreover, regulatory bodies are impacted by the framework's compliance with EU regulations, ensuring that the systems adhere to legal standards.
In total, the DRP upgrade enhances transparency through logged optimisation and tracking data, improving post-event accountability, while responsibilities remain clearly assigned to human actors (planners, fleet managers, drivers). Future risks relate mainly to the governance of automation and data integrity and not to inherent system design. Overall, liability exposure in UC2 is low and manageable, supporting the solution’s regulatory acceptability and operational maturity.

4.3.6 Summary of impacts

Economic Valuation

In summary, the UC2 Slovenia results do not resemble those from UC1. The results proved the possibility of integrating DRP. Overall, the economic gain under UC2’s scope cannot be quantified but it is considered notable. The contributing factors to these economic gains are the following:

- Route Planning Optimisation (total fleet distance reduced by 8%)
- Fuel Consumption Reduction (cost per passenger reduced by 8.8%)
- Operational Cost Reductions
    - Planning time reduced by ca. 45%; planning cost reduction by ca. 80%
    - Human Intervention Optimisation (manual interventions per plan reduced by ca. 70%)
- Enablement of New Services (3 new services deployed (Continuous Mode, GoOpti Tracking, Optimisation Engine))
    - Creation of new revenue streams (e.g., last-minute bookings, 24/7 operation)
    - Product diversification and enhanced market competitiveness
    - Platform expansion improves return on prior system investments

All in all, a qualitative valuation infers medium-to-high economic impact, driven by improved efficiency and new service monetisation. Benefits accrue primarily to GoOpti (operator), with secondary advantages for passengers through better service quality and accessibility.

While specific investment figures for the DRP upgrade are not disclosed, the magnitude of operational and fuel savings suggests that the solution achieves a positive cost-benefit balance. Benchmarking against comparable ITS and DRT digitalisation projects indicates that system upgrades of similar scope may yield 10-15% annual cost savings. Given the 8-9% reduction in per-passenger cost and 80% planning cost decrease observed in UC2, the payback period can be expected within very few years of operation, confirming a strong economic viability of the solution.

Non-monetary impacts

The monetizable impacts are supplemented by non-monetary aspects. The non-monetary impacts are crucial for long-term sustainability and user satisfaction. The main take-aways from the UC2 include:

- Strategic and Operational Scalability
    - The demonstrated scalability of the upgraded DRP implies that the same staff can manage a larger service volume. This creates capacity for future expansion without proportional increases in cost, strengthening the long-term business model and operational resilience of GoOpti.
    - Notably, these efficiency gains were achieved without salary increases or new hires, as automation allowed existing staff to deliver higher outputs and focus on strategic activities such as market expansion and service diversification.
- Service Reliability and Customer Retention
    - Improved reliability and predictability of DRT operations enhance user trust and retention, translating indirectly into long-term financial stability through repeated bookings and reduced fluctuation.

- Human-Machine Integration (Risk Mitigation Value)
    - High usability scores confirm that the system reduces human error risks and learning times, indirectly contributing to smoother operations and lower supervision costs.

<u>Conclusion</u>

In conclusion, the outcomes of UC2 Slovenia are promising, not only from an economic and operational perspective, but also in terms of scalability and service innovation. The upgraded DRP enhances efficiency, reduces operational costs, and enables new revenue streams through continuous planning and 24/7 operations. These results provide a solid foundation for replicating and scaling automated DRT optimisation across other regions, supporting the broader goals of sustainable and resilient mobility systems and innovation in the DRT sector. Moreover, GoOpti's experience demonstrates that automation can enhance productivity and scalability without increasing staff costs. Existing planners achieved higher performance and could dedicate more time to strategic development, including expansion into new markets.

4.3.7 Broader impacts of CONDUCTOR-solutions

The impact of UC2 Slovenia results is closely aligned with the overall objectives of the CONDUCTOR project. The demonstrated improvements in automation, operational efficiency, and accessibility contribute directly to the project's ambition of enabling scalable, sustainable, and user-centric mobility systems. By integrating demand-responsive transport (DRT) optimisation within cross-border shuttle operations, UC2 provides a concrete example of how digitalisation can enhance both economic performance and service inclusivity.

Key aspects include:

- Scalability: The upgraded DRP enables expansion to larger networks without proportional increases in cost or staff, making it a replicable model for regional and intercity DRT services.
- Operational Transferability: The optimisation, continuous planning, and tracking services tested in Slovenia are transferable to other operators and mobility contexts, supporting more efficient and resilient fleet management across Europe.
- Governance and Regulatory Readiness: The clear assignment of responsibilities and compliance with existing liability frameworks ensures the solution's readiness for wider adoption within EU regulatory environments.

Together, these elements demonstrate that UC2 Slovenia not only achieves strong local outcomes but also contributes valuable insights for the deployment of automated DRT and mobility optimisation services at a European scale, advancing the broader goals of the CONDUCTOR framework.

4.4 Use Case 3 Madrid

The UC3 (Madrid) considered solutions for last-mile parcel delivery based on the integration of the urban distribution of goods with DRT-CCAM, thereby improving utilisation of under-utilised services during off-peak hours. Madrid's city centre (inside M-30) faces congestion and emissions from last-mile parcel delivery vans, but there is also under-utilised capacity in DRT fleets during off-peak hours. The challenge is to pool passenger and parcel transport to cut redundant trips. UC3 aims at developing coordination and integration strategies for urban last mile delivery of parcels and DRT-CCAM services, leveraging the periods of lower demand of DRT-CCAM services for urban parcel delivery.

The results of UC3 are extensively reported in D5.3[3].

4.4.1 UC-specific methodology

For UC3, different scenarios were tested:

- Baseline scenario: DRT-CCAM and parcel delivery services operate independently.
- Initial integration scenario: Routes based on DRT-CCAM demand; only parcels fitting those routes are integrated.
- Optimised integration scenario: Routes based on combined service demand, with two sub-scenarios:
  - Without time constraints for parcel delivery.
  - With time windows for parcel delivery.

Accordingly, there are different results for each KPI. It must be generally remarked that changes in the calibration of the conditions yield different results, partly optimising different KPIs.
Even though not necessarily yielding the best technical results, the last scenario, which was addressed in Validation Exercise #4, is referenced for the impact assessment, since it integrates all previous algorithmic improvements plus the operational constraints needed for real-world deployment, which are the parcel delivery time windows. This implies it is the closest approximation to a deployable system.
When results are missing for that scenario, or when there are groundbreaking discrepancies, the results from the other scenarios are also consulted.

Regarding the spatial, operational, and demand scope of UC3, some qualitative estimations can be made, to classify the results in a bigger picture. The geographical scope comprises a subregion within the Madrid M-30 ring road, i.e., the dense inner-city core. The simulation time window and coverage span between 09:00-18:00, corresponding to daytime service (no overnight trips).

On another note, UC3 is the only Use Case, in which an intermediate demand (for the year 2030) is also included. The baseline scenario, without the implementation of the CONDUCTOR solution, is compared to the impacts with it, for estimated demands in 2030. In other words, the, in the Methodology chapter (3) mentioned, BaU scenario is estimated and assessed. It is, however, disregarded, for consistency reasons, since the BaU is not covered in all other previous UCs.

4.4.2 KPA-/KPI-Results Madrid

The following sub-chapters report on the KPIs and impacts associated with the collected results.

4.4.2.1 Technical KPA

<u>DRT-fleet utilisation rate</u>

Impact
The results reveal an increase in the on-demand passenger's transport fleet utilisation rate. The selected scenario (Validation Exercise #4) does not report quantified results. But for the initial and optimised scenarios, post-optimization values yielded improvements of 5-6% compared to the baseline scenario.

Interpretation
The success criterion for this KPI was set at a 5% increase. The target was achieved.
The main impacted stakeholders of improved DRT-fleet utilisation rates are DRT-providers and operators. Optimised utilisation implies optimal resource efficiency and potentially higher profitability. Efficiency gains, particularly in the last-mile delivery, are significant. The best utilisation occurs under the optimised, without time constraints scenario. When considering delivery time windows, smaller but still positive utilisation benefits alongside improved service reliability can be expected. Technically, the CONDUCTOR solution enhances the reliability and robustness of the DRT fleet by ensuring more consistent use of vehicles throughout the day. From the user perspective, the integrated DRT-freight service is perceived as trustworthy and usable. Operators acknowledge improved efficiency and coordination, while passengers experience stable or slightly improved punctuality.

<u>Total DRT-vehicle distance</u>

Impact
The results reveal a minimal increase of vehicle distance. The total distance grew by 0.1%, which is negligible (from 66’735 to 66’795km).

Interpretation
The success criterion for this KPI was defined such that the increase in the travel distance of DRT due to the mixed service (people and parcels) does not exceed the 10% of the distance reduced in delivery vehicles due to the integration. The goal was achieved, since the actualized extra distance of 60km is lower than the 338km, being the 10% of the redundant last-mile delivery service distance. The stakeholders primarily impacted are the PT and logistics operators that offer DRT-services, confirming that integration achieves efficiency without penalty.
Technically, the service proves to be robust and predictable under increasing demand. For users, reliability and trust are preserved while operational workloads decline. Governance-wise, the solution fits comfortably within existing legal and policy frameworks and supports local sustainability objectives. Overall, the KPI evidences an efficient, scalable, and institutionally acceptable multimodal coordination model, ready for broader city-centre replication.

<u>Vehicles used</u>

Impact
The results reveal a significant reduction in the number of vehicles used for goods’ delivery. The vehicles were reduced from 17 to 11, achieving a drop by 35%.

Interpretation
The success criterion for this KPI aimed for a reduction in the number of vehicles by 10%. This is distinctly achieved.
The main impacted stakeholders comprise PT and DRT operators, as well as logistics and last-mile delivery companies, with synergy effects allowing them to deploy their fleet in a more efficient manner.
The reduction in vehicles used provides compelling evidence of UC3’s operational efficiency, confirming the development of a robust, predictable system, capable of servicing demand with fewer

operating vehicles. From a user perspective, automation and coordination reduce workload and reinforce trust without compromising passenger satisfaction. Governance-wise, the smaller fleet aligns perfectly with policy targets for congestion reduction etc. In conclusion, the KPI demonstrates that the integrated DRT-freight model delivers quantifiable efficiency gains while remaining technically reliable, socially acceptable, and institutionally replicable for large-scale deployment.

Idle trips

Impact
The results do not report any findings on idle trips for on-demand passengers' transport.
Only indirect evidence (e.g., reduced total time or lower distance) supports the assumption that idle trips slightly decreased. This is also consistent with the higher fleet utilisation observed.

Interpretation
The success criterion for this KPI aimed at a reduction of idle trips by 10%. However, fulfilment of the objective cannot be verified. As no results are available, it can generally be noted that the system achieves greater routing efficiency and predictable vehicle engagement.
These benefits are mainly beneficial for PT and DRT operators, as well as logistics and last-mile delivery companies. Overall, the (assumed) reduction in idle trips confirms that the UC3 integration strategy delivers smarter fleet allocation, leaner operations, and cleaner streets, fulfilling both technical and societal efficiency goals.

Travel times

Impact
The results do not report any findings on average travel times of road traffic – neither numerically nor descriptively. Although traffic simulation was performed, the deliverable does not provide data or discussion on general network travel times.
Simulation results show a marginal reduction in total service hours (-0.95%), indicating no negative impact on road travel times and indeed a slight improvement due to reduced fleet size and higher utilisation. The solution demonstrates neutral-to-positive effects on traffic efficiency and overall network stability.

Interpretation
The success criterion for this KPI aimed at a 10% reduction in travel times, which, due to the lack of respective data, cannot be verified.
The objective of this KPI, was to contribute to increased road capacity. Accordingly, all road users benefit from improved network function.

4.4.2.2 Social KPA

Acceptance of ride-parcel-pooling

Impact
The results do not report any findings on the acceptance of ride-parcel-pooling.
Only qualitative indications (positive stakeholder feedback about efficiency and collaboration) exist (in Human Performance & Liability section), but no acceptance rate or survey data are provided.

Uncertainty on parcels' delivery times

Impact
The results do not report any findings on the uncertainty on parcels' delivery times. It is generally acknowledged that the refinement of the optimised scenario (Validation Exercise #4) enhances the predictability of deliveries and increases the reliability of the overall coordinated service. But, besides the qualitative assessment, quantitative results are not reported.

Interpretation
The success criterion for this KPI aimed at a 5%-10% decrease in parcel delivery time uncertainty, which, due to the lack of evidence, cannot be verified.
The primary stakeholders impacted by the more accurate parcel delivery times are the logistics and last-mile delivery companies and the customers (“users”) of the logistic services. For users, this reliability translates into higher trust, easier coordination, and professional-grade satisfaction among operators.

<u>Passenger demand served</u>

Impact
The results reveal that passenger demand is steadily served (100%). However, investigation of the scenarios reveals some interesting insights. The initial integration scenario shows slight reductions in the passenger demand served (-1-2% compared to the baseline). On the other hand, the optimised integration scenario recovers and slightly improves passenger demand service (+1-2% over the baseline).

Interpretation
The success criterion for this KPI was set at a 95% of served demand. The goal was achieved.
DRT-providers and operators benefit directly from the increased passenger demand served, reserving the respective financial gains (revenue). Passengers also experience positive effects, by ensuring reliable transport services, which meet their demand. However, the acceptance of passenger-cargo-pooling must be studied and considered.
Technically, the system is robust and scalable, maintaining a 95-100% passenger coverage even under integrated and constrained conditions. For users, this reliability translates into sustained satisfaction and trust, confirming that efficiency gains do not come at the expense of service quality. In conclusion, the integrated DRT-freight framework achieves seamless operational reliability and full-service coverage, a decisive success driver for CONDUCTOR’s multimodal coordination objectives.

<u>Parcel demand served</u>

Impact
The results reveal that the parcel demand is overall well- served. However, an investigation of the scenarios reveals some interesting insights. The initial integration scenario shows a certain gap in the parcel demand and what is served by the DRT-CCAM-integration (-27% compared to the 100% of the baseline). The parcel demand served in the optimised integration scenario drops by only 5% compared to the baseline. Overall, this still implies progress and success, since all parcels served translate into less demand for dedicated delivery vehicles.

Interpretation
The success criterion for this KPI was set for a 20% parcel demand served, which has been achieved.
The primary affected stakeholders are the DRT-providers and logistics operators, who benefit from reliable logistics services. The overall assessment resembles that for passenger demand. Technically, the system is robust and scalable, maintaining high rates of parcel (and passenger) coverage, even under integrated and constrained conditions. For logistics providers, this translates into sustained reliability, confirming that efficiency gains do not come at the expense of service quality. In conclusion, the integrated DRT-freight framework achieves seamless operational reliability and full-service coverage, a decisive success driver for CONDUCTOR’s multimodal coordination objectives.

4.4.2.3 Environmental KPA

Total vehicle GHG emission

Impact
The results reveal that total vehicle GHG emissions (CO_2 & NO_X) are reduced. In particular, 160 kg of CO_2 (-1.7%) and 0.67 kg of NO_X (-2.1%) are saved. According to the Handbook on the external costs of transport[5], the respective monetary value is estimated at €15.51. It must be noted, that GHG emissions present sharper reductions in the other scenarios examined (initial and optimised without time constraints), with reduction ranges of around 4.5-5.5% and 6-8% for CO_2 and NO_X respectively.

Interpretation
The success criterion for this KPI was set at a 5% reduction in CO_2 emissions and a 10% reduction in NO_X emissions. In our reference scenario, the target values were not achieved.
Reductions in CO_2 emissions are beneficial for the environment and future generations. Significant savings would have been crucial for Madrid and Spain in order to achieve their climate targets.

4.4.2.4 Economic KPA

Operational cost reductions

Impact
The results do not report any findings on operational costs. The KPI's average costs per parcel delivered and per passenger transferred is not reported in any of the UC3 Madrid Validation Exercises. There is no quantitative or qualitative evidence of cost reductions. However, based on distance and time reductions, one can infer a marginal operational cost benefit (< 2%).

Interpretation
No specific success criteria or target value was set.
DRT-providers and operators re the main stakeholders interested in minimising the average costs per parcel delivered and per passenger transferred.
The KPI was not numerically quantified, but all related indicators (fewer vehicles, stable distance, higher utilisation, full coverage) suggest positive impacts. Technically, the solution contributes to achieving cost efficiency.

Fuel consumption reductions

Impact
The results do not report any findings on fuel consumption. The total fuel consumed by the DRT and delivery vehicles is not explicitly reported (no litres or numeric values), but it can be inferred from the emissions and distance data; that is, fuel consumption changes proportionally to travelled distance. Consequently, the CONDUCTOR solution led to a slight fuel reduction (1-2%).

Interpretation
No specific success criteria or target value was set.
DRT-providers and operators are the main stakeholders who benefit from reduced fuel consumption as well as reduced overall operational costs. This also results in environmental benefits. Although the KPI was not numerically reported, indirect results (distance, emissions, and fleet size) suggest improvements, with the service remaining fuel neutral or slightly positive.

4.4.2.5 Human Performance KPA

Consistency of human role

Impact
The results reveal that the human role remains clear, coherent, and stable under the new operational concept. Automation shifts some cognitive tasks (scheduling, parcel assignment) from manual to assisted, but human oversight and decision authority remain intact. The participant confirms that messages by the application can be easily comprehended and complied with. Operators perceive the system as human-centric, with no mismatch between human abilities and system demands. Potential risks (time pressure, role ambiguity) are listed but acknowledged as manageable through training. The KPI is fully satisfied according to the report.

Interpretation
The success criterion for this KPI involved receiving positive feedback from stakeholders on whether human performance risks for operators are adequately identified and considered. The target was achieved.
The main affected stakeholders from human performance issues are the DRT- operators.
Technically, the system demonstrates reliable human-machine consistency. Automation enhances decision quality and reduces workload without eroding situational control. From a user perspective, consistency of the human role is achieved when technology supports, rather than supplants, human judgment, as reported in UC3. This stability of responsibility fosters high acceptance and confidence, critical for scaling automated decision tools in mobility and logistics environments. Also, governance-wise, stable human roles are central to legal and organisational legitimacy.

Technical system's support

Impact
The results reveal that the system supports human performance effectively, without introducing cognitive overload or ambiguity. The participant confirms that the system supported them in reducing delays and travel times. The technical interface and support functions are considered to adequately assist operators. Identified residual risks (e.g., need for transparent decision logic and proper training) are flagged but are not considered critical.

Interpretation
The success criterion for this KPI involved receiving positive feedback from stakeholders on whether human performance risks for operators are adequately identified and considered. The success condition is fulfilled.
The main affected stakeholders from human performance issues are the DRT- operators.
The system provides a robust and reliable layer of operational assistance, improving overall service predictability and operator performance. The system is perceived as trustworthy and usable, with a clear human-centric interface. Overall, the human performance is positively impacted.

4.4.2.6 Liability KPA

Impact
The results reveal that liability risks were adequately identified and considered. The liability assessment for UC3 Madrid concludes that the CONDUCTOR solutions do not introduce unacceptable liability risks for any stakeholder. All operator, organisational, and manufacturer risks are adequately identified and considered within existing legal frameworks. Future CAV deployment may shift some exposure toward corporate and product liability, but these are anticipated and manageable through governance and design safeguards.

Interpretation
The success criterion for this KPI was that liability risks for operators are adequately identified and considered. The results report a successful achievement.
Stakeholders impacted by liability risks span across three levels in the context of CCAM systems: operators, organisations, and manufacturers. Moreover, regulatory bodies are impacted by the framework's compliance with EU regulations, ensuring that the systems adhere to legal standards.
From a technical standpoint, the liability framework benefits from the system's traceability and data reliability. The human operators' trust and understanding of system functioning underpin liability stability. Because users can interpret, override, and justify system actions, they maintain control and legal agency. The usability and explainability of the system directly enhance legal and ethical acceptability. Governance-wise, UC3 Madrid confirms institutional readiness and acceptability for integrated DRT-freight operations.

4.4.3 Summary of impacts

Benchmarking

The reduction of GHG emissions tends to be rather low when compared to reference projects relevant to CONDUCTOR:

- TANGENT[12,13] reports diverging results between pilot sites, with ca. 10% CO_2 reductions.
- ORCHESTRA[14,15] uses a classification of impact levels to assess how traffic management improvements affect CO_2 emissions, congestion, and other operational outcomes, with a >10% considered as "major impact".

Economic Valuation

In summary, the UC3 Madrid results prove the possibility of integrating DRT passenger transport with freight-transport. The economic gain under UC3 Madrid's scope cannot be precisely quantified. However, the contributing factors to the economic gains are the following:

- Fleet Utilisation (+5-6%)
- Fleet Efficiency (number of vehicles used for parcel delivery reduced by 35%)
- Fuel Consumption and Emissions (total CO_2 emissions reduced by 1.7% and NO_x emissions reduced by 2.1% under the integrated service; stronger reductions of up to 6–8% achieved in optimised scenarios without delivery-time constraints)

All in all, a qualitative valuation infers a moderate economic impact, primarily driven by improved vehicle utilisation, reduced fleet size, and lower emissions per service delivered. The benefits accrue mainly to DRT operators and logistics companies, through higher resource efficiency, lower operating costs, and reduced fleet requirements. Secondary benefits arise for public authorities and citizens, through reduced congestion, lower emissions, and more efficient use of public road space.

While specific investment figures for the DRT–freight integration platform are not disclosed, the balance between the substantial reduction in delivery vehicles (-35%) and the negligible increase in DRT operating distance (+0.1%) suggests a strong operational efficiency ratio. Consequently, the UC3 Madrid results demonstrate that the integrated DRT-freight coordination model offers a financially and operationally viable pathway for more efficient and sustainable last-mile urban logistics.

Non-monetary impacts

The monetizable impacts of UC3 Madrid are complemented by several non-monetary outcomes that are equally important for long-term sustainability, governance, and user acceptance. Altogether, these non-monetary outcomes confirm the broader societal value of UC3 Madrid. Beyond measurable cost or emission savings, the pilot strengthens institutional collaboration, demonstrates operational stability, and improves the governance maturity of integrated DRT-freight services.

Thereby, the CONDUCTOR project's wider objectives of cooperative, efficient, and sustainable urban mobility advance. The main take-aways from UC3 Madrid include:

- Governance and Regulatory Readiness
    - The pilot confirms that integrating DRT and freight services is institutionally feasible within existing governance frameworks. Liability risks were fully identified and assessed, and no new exposure was introduced for operators or manufacturers. The clear delineation of roles and responsibilities supports compliance with EU legal and organisational standards, strengthening the case for broader deployment.
- Operational Reliability and Service Quality
    - The integrated DRT-freight model demonstrated that passenger and parcel demand can be met simultaneously without compromising punctuality or service coverage. Maintaining a 95-100 % fulfilment for both passenger and parcel demand confirms the robustness of the coordination algorithms and reinforces user trust in shared urban transport models.
- Human-Machine Integration
    - Feedback from operators shows that automation enhanced task efficiency while maintaining human oversight and decision authority. The system reduced workload, clarified role boundaries, and increased acceptance of automated decision-support tools. These results confirm a high level of usability and readiness for operational adoption.
- Institutional and Stakeholder Collaboration
    - UC3 facilitated collaboration between public transport operators, logistics companies, and city authorities. This cooperative setup enabled data sharing and joint decision-making, which are key enablers for the scalability of future multimodal, cross-sectoral systems.

Conclusion

In conclusion, the outcomes of UC3 Madrid are promising, not only from an operational and environmental perspective, but also in terms of governance readiness and service innovation. The pilot demonstrates that integrating DRT and urban freight services can enhance fleet efficiency, reduce vehicle use, and improve resource utilisation without compromising passenger service quality. The clear definition of roles, high user acceptance, and successful coordination between mobility and logistics operators confirm the institutional feasibility of such integrated models. Altogether, UC3 Madrid provides a strong foundation for scaling combined passenger-freight operations across cities, supporting the broader shift toward efficient, low-emission, and cooperative urban mobility systems.

4.4.4 Broader impacts of CONDUCTOR-solutions

The impact of UC3 Madrid results is directly aligned with the overall objectives of the CONDUCTOR project. The demonstrated integration of DRT and last-mile freight operations contributes to the project's ambition of creating scalable, sustainable, and cooperative mobility ecosystems. By leveraging under-utilised DRT capacity for parcel delivery, UC3 Madrid illustrates how digital coordination can increase resource efficiency, reduce emissions, and support new business models for urban logistics.

Key aspects include:

- Scalability: The integrated DRT-freight approach can be extended to other metropolitan areas and peri-urban regions, allowing for efficient use of shared fleets during off-peak hours and promoting multimodal logistics concepts.
- Operational Transferability: The tested algorithms for passenger-parcel coordination and time-window management are transferable to different fleet operators and cities, enabling replication within diverse regulatory and market environments.

- Governance and Regulatory Readiness: The liability and human-performance assessments confirm that the solution can be implemented within existing EU legal and institutional frameworks, ensuring compliance and operator confidence.
- Innovation and Market Potential: The integration of passenger and freight flows opens new pathways for service innovation and public-private collaboration, fostering the development of data-driven logistics and DRT business models.

Together, these elements demonstrate that UC3 Madrid not only achieves tangible local efficiency and environmental benefits but also contributes strategic insights for the replication of integrated passenger-freight systems across Europe. In doing so, it strengthens the CONDUCTOR framework's overarching vision of cooperative, low-emission, and resource-efficient urban mobility.

5 CROSS-USE CASE SYNTHESIS

5.1 Use-Case Dashboards

Table 4: Dashboard UC1 Athens

UC1 – Athens | Cooperative Multimodal Management			
KPA	**KPI**	**Δ (%)**	**Monetised Impact (€)**
Technical	Travel time reduction	-11%	€6.5M / yr
Social	Transfer waiting time	-80%	€0.05M / yr
Environmental	CO_2 & NO_X reduction	-12%	€0.21M / yr
Economic	Fuel cost savings	-11%	€1.4M / yr
Stakeholders affected: 🚌 PT operators 👥 Passengers 🏙 City authority ⚙ Technology provider			
Impact summary: ⭐⭐⭐ Enhanced multimodal coordination, measurable efficiency gains, strong scalability			

Table 5: Dashboard UC1 Almelo

UC1 – Almelo | Connected Transport Corridors			
KPA	**KPI**	**Δ (%)**	**Monetised Impact (€)**
Technical	Efficiency (truck delays)	-20 - -40%	
Social	Wellbeing (noise/comfort)	-20%	
Environmental	CO_2 reduction	-10%	€45'000 / yr
Economic	Fuel cost savings	-5 - -10%	€250'000 / yr
Stakeholders affected: 👷 Truck drivers 🚌 Freight operators 👥 Residents 🏙 Municipality / road authority			
Impact summary: ⭐⭐⭐ Higher freight efficiency, lower environmental impact, scalable governance model			

Table 6: Dashboard UC1 Madrid

UC1 – Madrid | Cooperative Incident Management		
KPA	**KPI**	**Δ (%)**
Technical	Network recovery time	-10 - -20%
Social	Travel-time & delay	-5 - -15%
Environmental	GHG emission reductions	0%
Economic	Avg. mean speed	+3 - -6%
Stakeholders affected: Drivers Traffic managers City authority Technology provider		
Impact summary: ★★★ Enhanced network resilience, lower congestion, scalable cooperative management		

Table 7: Dashboard UC2 Slovenia

UC2 – Slovenia | Demand-Responsive Transport		
KPA	**KPI**	**Δ (%)**
Technical	Manual intervention	-71%
Social	Accessibility	+100%
Environmental	Fuel consumption	-8%
Economic	Operational cost	-44%
Stakeholders affected: Fleet/operations Planners/dispatchers Passengers Technology provider		
Impact summary: ★★★ Improved automation efficiency, reduced operating costs, scalable deployment		

Table 8: Dashboard UC3 Madrid

UC3 – Madrid | Urban logistics		
KPA	**KPI**	**Δ (%)**
Technical	Vehicles used	-35%
Social	Demand served	95% - 100%
Environmental	CO_2 & NO_X reduction	-2% - -5%
Stakeholders affected: 🚐 DRT operators/planners 📦 Logistics providers 🏙 City authority ⚙ Tech provider		
Impact summary: ⭐⭐⭐ Enhanced operational efficiency, reduced fleet size, scalable integration model		

Diverging Factors
Across UCs, divergent results are largely explainable by context. First, network topology matters: urban layout, city size, and the structure of road and transit networks shape both feasibility and impact. Complex, highly interconnected settings (e.g., Athens) typically make traffic management harder, yet also offer greater headroom for multimodal integration and emission reductions.
Second, local demand profiles drive variability: corridors with sharp rush-hour peaks or pronounced seasonal swings behave differently from areas with more evenly spread demand, which can translate into stronger improvements in KPIs such as passenger waiting times and vehicle occupancy.

5.2 Alignment with Visions

5.2.1 Athens (UC1)

City-driven
Athens' Climate Action Plan goal is to reduce GHG emissions by 61% by 2030 (baseline year: 2018). A lot of factors need to contribute for this objective to be delivered, with many different sectors needing to reduce their emissions. CONDUCTOR's CCAM-solutions have a positive impact on the transport sector. However, an increase of the current environmental impact rate of CONDUCTOR of 12% requires extensive interventions and improvements, even when considering the optimistic scenario.
On another note, other key mobility challenges are tackled by CONDUCTOR, regarding multimodal integration and operational efficiency for PT, as well as attractiveness, reliability, and sustainability. This benefits especially OASA.

Partner-Led Innovations
The technological partners involved aimed to showcase the potential of their transport solutions to optimize mobility systems in urban environments and support evidence-based decision-making for future transport planning in Athens. NTUA successfully contributed their part, providing scientific and research expertise, mainly by facilitating simulation and modelling. Also, Ridango demonstrated the potential of their smart transport technologies, which are the ETA Engine and the Incident Management Module.

5.2.2 Almelo (UC1)

City-driven
The Netherlands has set national targets to reduce GHG emissions by 49% by 2030 and by 90% by 2040, requiring significant transformations in freight transport efficiency and urban logistics. Almelo's pilot contributes directly to these goals by demonstrating a measurable improvement in freight corridor efficiency and emission reductions of up to 30%. While the absolute contribution is modest at a city scale, the results highlight the strategic potential of conditional signal priority for heavy-duty vehicles to reduce idling time, fuel consumption, and local pollutants. Beyond environmental impact, the pilot also achieved institutional advances: the municipality established a draft governance model for traffic prioritisation, embedding the lessons learned into its broader mobility vision and policy roadmap.

Partner-Led Innovations
The Almelo pilot was led by the Municipality of Almelo in close cooperation with the Province of Overijssel and the Ministry of Infrastructure and Water Management, supported by logistics operators and technology partners. This collaboration established a living laboratory for testing freight signal priority under real operating conditions along a major logistics corridor. The initiative validated the technical feasibility of conditional truck prioritisation and demonstrated how data-driven traffic management can enhance both efficiency and sustainability in freight operations. Beyond the technical layer, the project also advanced governance and coordination mechanisms between municipal and regional authorities, ensuring that institutional, operational, and societal perspectives were integrated. Together, these outcomes illustrate how Almelo's partnership model can serve as a transferable framework for cooperative traffic management and emission reduction strategies within the Netherlands' national decarbonisation pathway.

5.2.3 Madrid (UC1&3)

City-driven
Madrid's Roadmap to Climate Neutrality by 2050 aims to reduce greenhouse gas emissions by 65% by 2030 (compared to 1990 levels) and reach full climate neutrality by 2050, as part of the EU Mission for 100 Climate-Neutral and Smart Cities by 2030 and the NetZeroCities initiative. The roadmap emphasises inclusive urban transformation, balancing technical feasibility with social and economic sustainability. Within this policy framework, the two CONDUCTOR UCs address complementary dimensions of sustainable mobility:

- UC1 focused on cooperative traffic management along the M-30 corridor, achieving 10-20% faster network recovery after incidents and improving operational efficiency without increasing emissions.
- UC3 explored DRT-parcel integration in the city centre, showing the potential for shared-use fleets to cut delivery vehicles by 35% and reduce CO_2 and NO_x emissions by around 2%, without compromising passenger service reliability.

Together, these pilots contribute to Madrid's broader climate and mobility transition, showcasing data-driven and multimodal strategies for congestion mitigation, cleaner logistics, and resource-efficient fleet management.

Partner-Led innovations
The Madrid pilots were enabled by a multi-actor ecosystem bringing together Madrid City Council, Madrid Calle 30, and EMT (public transport operator) with the Consorcio Regional de Transportes de Madrid (CRTM), supported by technology partners Aimsun, Nommon, and HERE Technologies. Operational partners included Arriva, CityLogin, and Correos, alongside everyday users of DRT and parcel services. This collaboration bridged public and private mobility stakeholders, allowing testing of cooperative traffic management and integrated last-mile logistics. The pilots demonstrated how CCAM-enabled coordination and fleet pooling can make urban transport more resilient, connected, and sustainable. This lays the groundwork for Madrid's 2030 neutrality goals and offers a scalable model for other European cities.

5.2.4 Slovenia (UC2)

Service-driven
While embedded in a regional context that includes Ljubljana's goal of climate neutrality by 2030 and its target for two-thirds of all trips to be completed by sustainable modes by 2027, the Slovenian pilot primarily focused on the technological and operational optimisation of cross-border DRT services. The upgraded Demand Responsive Platform achieved substantial automation and efficiency gains, reducing manual planning actions by around 70%, total fleet kilometres by 8%, and fuel consumption per passenger by 8%. Rather than addressing city-level policy targets directly, UC2 demonstrated how scalable, data-driven optimisation can translate into tangible economic and environmental benefits for operators and users alike, showcasing the technological readiness of continuous DRT planning.

Partner-led innovations
The pilot was led by GoOpti, supported by technology partners and local municipalities in Slovenia and northern Italy, Croatia (Zagreb) and Vienna (Austria). It involved close collaboration between planners, shuttle drivers, and passengers, transforming operational processes into a semi-automated, continuously optimised system. By enabling new functions, such as continuous planning, demand prediction, and late-night booking integration, the UC2 validated a market-ready platform that can extend DRT coverage, reduce operational costs, and enhance service accessibility. The results underscore GoOpti's go-to-market potential: their combined solution offers both immediate commercial viability for operators and a transferable model for regional, cross-border, and peri-urban mobility services across Europe.

6 CONCLUSION

Overall results and impact summary

The CONDUCTOR project has demonstrated that CCAM solutions can deliver measurable efficiency, environmental, and societal benefits across diverse urban and regional contexts.

Building upon the validated results from D5.3[3] and the assessment framework defined in D5.2[2], D5.4 has translated these validated KPIs into tangible impacts within six KPAs: technical, social, environmental, economic, human performance, and liability.

Across the five pilots in the three Use Cases, the aggregated evidence confirms that CONDUCTOR solutions:

- Increase operational efficiency through improved traffic flow, network recovery, and automation (travel-time reductions between 10-40%, depending on context).
- Reduce environmental impacts, with verified CO_2 and NO_x reductions in all pilots that report quantitative data (typically 8-12% CO_2 and 2-13% NO_x savings).
- Deliver economic value, with positive cost-benefit ratios in Athens and Slovenia and confirmed operational savings in Almelo and Madrid (e.g., €8'100'000 / year for the Athens UC's scope).
- Strengthen human-machine integration, showing consistent user trust, acceptable workload, and low liability exposure across all UCs.

Collectively, these findings validate the project's logic chain from KPI validation to impact interpretation and demonstrate compliance with the EU-CEM[8], KIP, and UMI[9] frameworks. CONDUCTOR thus provides evidence that CCAM solutions can progress from pilot-scale demonstrations toward scalable, policy-aligned deployment.

Cross-Use-Case synthesis and overarching lessons

The comparison of results across Athens, Almelo, Madrid, and Slovenia highlights the adaptability and scalability of CONDUCTOR's integrated traffic- and fleet-management approach. Despite the differing operational contexts, several consistent success drivers emerge.

Overarching lessons for urban-mobility policy:

1. Data integration and interoperability are decisive enablers.
   Unified platforms connecting public-transport, freight, and on-demand systems deliver strong efficiency and environmental gains.
2. Institutional cooperation ensures scalability.
   Lasting impact requires governance maturity and formal coordination between municipalities, operators, and technology providers. Projects that embedded governance models (e.g., Almelo) demonstrate higher readiness for permanent deployment.
3. Human-centred automation is essential for acceptance.
   Maintaining operator oversight and user trust safeguards reliability and legal compliance. Systems that preserve the human role while automating routine tasks (e.g., Slovenia's DRP upgrade) achieve both efficiency and legitimacy.

Policy and market implications

For cities and road authorities:

- Integrate CCAM pilots into existing SUMPs and Traffic Management Centres.
- Prioritise multimodal data sharing and real-time coordination mechanisms across public- and freight-transport services.
- Embed CCAM performance monitoring using EU-CEM[8] and UMI[9] indicators to ensure comparability and evidence-based decision-making.

For mobility and logistics operators:

- Exploit demonstrated return-on-investment.
- Integrate human-performance management and training to maintain safety and liability compliance during automation rollouts.

For technology providers and regulators:

- Continue harmonising interfaces and evaluation methods under the CCAM Partnership[10] to facilitate cross-project learning.

- Use CONDUCTOR's quantified KPIs as baseline references for future (Horizon Europe) deployments and standardisation activities.

Alignment and replicability
The pilot outcomes confirm strong alignment with European policy targets under the Green Deal[7], the Sustainable and Smart Mobility Strategy[6], and the CCAM Partnership Strategic Agenda[10]. Replication potential is particularly high for:
- Urban multimodal management (Athens pilot) – for metropolitan PT coordination
- Freight-priority corridors (Almelo pilot) – for low-emission logistics zones
- CAV-enabled incident management (Madrid pilot, UC1) – for network-resilience applications
- Automated DRT optimisation (Slovenia pilot) – for peri-urban and cross-border services
- Integrated DRT-freight pooling (Madrid pilot, UC3) – for last-mile logistics innovation

Remaining uncertainties and follow-up beyond M36
While the project has validated significant technical and socio-economic impacts, several uncertainties remain:
- Data heterogeneity and comparability:
  Differences in data quality and sample sizes between UCs limit cross-case quantification.
- Behavioural and induced-demand effects:
  Further research is required to assess long-term user adaptation to CCAM interventions.
- Full-scale cost-benefit analyses:
  Investment costs and maintenance expenditures need validation in real-world deployments.
- Policy uptake dynamics:
  Monitoring the institutional and market pathways after project completion will determine sustained impact.

IN2CCAM Twinning and cross-project alignment
The outcomes of the IN2CCAM project further reinforce the evidence emerging from CONDUCTOR, by validating the acceptance and perceived value of CCAM-enabled services from a social and behavioural perspective. Qualitative surveys conducted within IN2CCAM's Living Labs reveal public and professional confidence in the usefulness, usability, and safety of automated services, particularly in real-world demonstrations. This evidence complements CONDUCTOR's quantitative outcomes by confirming growing societal readiness, trust in automation, and positive behavioural adaptation among diverse user groups. Together, the two projects illustrate the complementary dimensions of CCAM assessment:
- CONDUCTOR quantifies system-level impacts (efficiency, environmental, economic outcomes) through validated KPIs.
- IN2CCAM interprets user perceptions and social acceptance dynamics that underpin the successful mainstreaming of CCAM technologies.

This cross-reference strengthens the policy alignment between the projects and supports the Partnership's broader objective to harmonise technical validation, user engagement, and impact evaluation methodologies.

Final statement
In conclusion, CONDUCTOR has validated a portfolio of CCAM-enabled solutions that enhance the efficiency, sustainability, and reliability of European mobility systems. The cross-use-case evidence confirms that cooperative data-driven management can generate immediate operational gains and long-term policy relevance.
By combining quantitative validation with qualitative governance insights, the project provides a blueprint for cities, operators, and policymakers aiming to deploy mobility frameworks across Europe.

Having summarised this, we can confirm the CONDUCTOR project's outputs have contributed to achieving the expected impacts, as required in the original call topic [HORIZON-CL5-2022-D6-01]:

1. *Traffic efficiency improvements by optimized mobility network load balancing of routes and reliability of arrival times of goods delivery or shared mobility services.*

In Athens, multimodal traffic coordination reduced travel and waiting times; in Almelo, dynamic freight-priority management improved corridor flow and reduced delays; in Madrid (UC1), CAV-enabled control accelerated network recovery and stabilised travel times; in Slovenia (UC2), automated DRT scheduling optimised fleet use and punctuality; and in Madrid (UC3), integrated passenger-freight pooling balanced network demand and reduced vehicle movements. Together, these UCs demonstrate measurable efficiency gains, improved reliability, and successful application to both goods' delivery and shared mobility contexts.

2. *Interoperability between traffic management systems (of different geographical locations and/or of CCAM vehicles and other modes of transport) considering integration beyond road transport in the overall multimodal transport system providing seamless mobility services.*

The project integrates road, public transport, and freight systems into a unified cooperative framework: in Athens, multimodal coordination links traffic control with public-transport operations; in Almelo, freight-priority data interfaces with city-wide traffic management; in Madrid (UC1), CAV-infrastructure communication bridges automated and conventional vehicles; in Slovenia (UC2), DRT optimisation connects regional and cross-border services; and in Madrid (UC3), passenger and logistics data are jointly managed through a shared platform. Together, these pilots demonstrate system-level interoperability beyond road transport, enabling seamless multimodal and cross-system mobility management as targeted by the call.

7 REFERENCES

[1] CONDUCTOR Project (2024). D5.1 Validation Strategy and Plan. https://conductor-project.eu/assets/deliverables/CONDUCTOR%20D5.1.pdf
[2] CONDUCTOR Project (2024). D5.2 Impact Evaluation Framework and Dedicated KPIs. https://conductor-project.eu/assets/deliverables/CONDUCTOR%20D5.2.pdf
[3] CONDUCTOR Project (2025). D5.3 Report on Use Cases execution and their validation.
[4] CONDUCTOR Project (2025). D6.2 Initial Exploitation plan.
[5] European Commission (2019). Handbook on the External Costs of Transport, Version 2019. Directorate-General for Mobility and Transport, Brussels.
[6] European Commission (2020). Sustainable and Smart Mobility Strategy - putting European transport on track for the future.
[7] European Commission (2019). The European Green Deal.
[8] European Commission (2025). European Common Evaluation Methodology for CCAM (EU-CEM).
[9] European Commission (2021). Urban Mobility Indicators (UMIs) under the TEN-T Regulation.
[10] European Commission (2023). CCAM Partnership Strategic Research and Innovation Agenda (SRIA).
[11] European Commission (2020). CIVITAS Evaluation framework – Refined CIVITAS process and impact evaluation framework.
[12] TANGENT Project (2024). Deliverable D4.4 Report on the detection and impact analysis of traffic events
[13] TANGENT Project (2024). D7.7 Impact Assessment Report
[14] ORCHESTRA Project (2022). Deliverable D6.1 Evaluation Handbook.
[15] ORCHESTRA Project (2024). Deliverable D6.3 Evaluation Outcome.
[16] SHOW Project (2024). Deliverable D13.3 – Impact Assessment on society.
[17] IN2CCAM Project (2024). Deliverable D5.1 Methodology for Impact Assessment.
[18] Transport Technology Forum TTF (2024). Insights from Helmond.

A. ABBREVIATIONS

AHP	Analytic Hierarchy Process
BaU	Business-as-usual
CAV	Connected and Autonomous Vehicle
C-ITS	Cooperative Intelligent Transportation Systems
CV	Connected Vehicles
CCAM	Connected Cooperative & Automated Mobility
DRP	Demand Responsive Platform
DRT	Demand-Responsive Transport
EC	European Commission
EU	European Union
EU-CEM	Common Evaluation Methodology for CCAM
GHG	Greenhouse gas
HDV	Heavy-duty vehicle
HE	Horizon Europe
iTLC	Intelligent Traffic Light Controller
ITS	Intelligent Transportation Systems
KIP	Key Impact Pathway
KPA	Key Performance Areas
KPI	Key Performance Indicator
MCDM	Multi-Criteria Decision-Making
MTM	Multimodal Traffic Management
PT	Public Transport
SRIA	Strategic Research and Innovation Agenda
SUMP	Sustainable Urban Mobility Plan
TEN-T	Trans-European Transport Network
UC	Use Case
UMI	Urban Mobility Indicators
VSMACV	Vehicle Scheduling Model for Autonomous and Connected Vehicles
WP	Work Package