From Self-Centered to Mutual Beneficial Traffic Orchestration: The CARMONY Use Cases and User Stories

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Abstract. Mobility needs are individual, depending on the motivation of a specific trip (professional context, commuting, leisure activities) and the user's background. In the superordinate traffic system, users are coming together to fulfil their needs. These can be made visible through individual user stories, while technical solutions for users and the superordinate system are elaborated through the definition of related Use Cases.

The Horizon Europe project CARMONY develops an Interlinked Orchestrator Framework for traffic management which offers personalised suggestions and balances individual needs and mutual societal benefit, while leaving the final decision to the user. The suggestions provided by the Framework derive from new governance models, Digital Twin monitoring, real-world traffic data and simulation studies.

This paper describes user stories and demonstration plans of six Use Cases from CARMONY: Three Use Cases in Murcia and three Use Cases in Luxembourg. Murcia Use Cases include Traffic Management Optimization in Urban Low Emission Zones, Critical Road Blockage and Traffic Orchestration during Emergency Corridor Activation. Luxembourg Use Cases feature carpool lane Optimisation, Innovative Mobility Services, Cross-border Highway Traffic Optimisation and Speed Reduction on Traffic Jam Avoidance.

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1 Introduction

In the last years, mobility in Europe has been heavily influenced by the increase in road traffic and congestion. 2024 reports indicate that, in large cities like London or Paris, drivers spent about 100 h per year stuck in traffic jams [1]. This does not only affect travel times but also causes an economic impact for drivers and cities [2].

Even beyond large metropolitan areas, congestion is an increasing challenge across Europe. Recent studies show that, without the implementation of corrective measures, travel times could significantly increase in several regions of the continent [3].

Traffic orchestration thus emerges as an essential strategy towards efficient mobility. In this context, CARMONY Horizon Europe project [4] introduces the concept of the Interlinked Orchestration Framework (Fig. 1), based on strategic planning backend and fast operating components, addressing the entire traffic orchestration process: from the design of governance and business models, including incentive structures that help competing actors in the transport system understand the benefits of orchestration, to the actual personalised recommendations to the users. Since its goal is not to impose decisions but to optimise traffic for everyone, it focuses on individual needs and provides personalised suggestions, while leaving the final decision to the user.

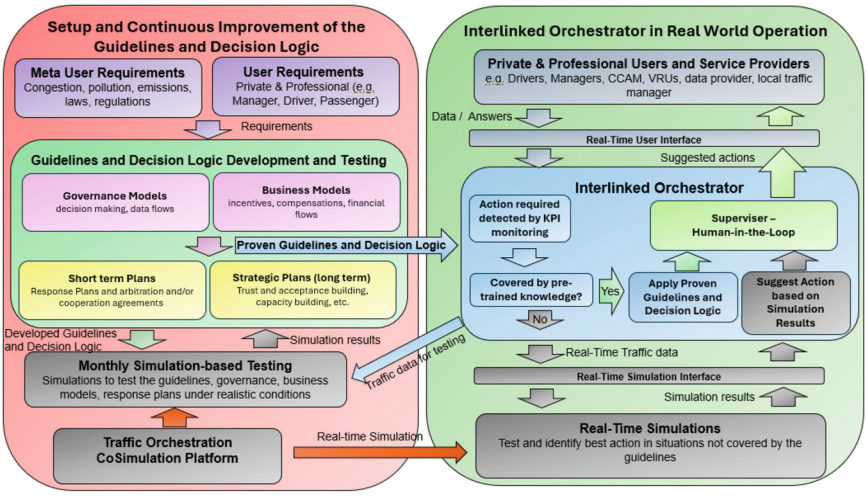


Fig. 1. Concept of the Interlinked Orchestrator.

The following sections describe the approach as well as the preliminary plans for the two pilot sites in Murcia and Luxembourg.

2 Methodology

To illustrate the potential impact of the solutions on users' daily lives, several User Stories have been designed and are presented alongside their corresponding Use Cases and pilot sites (see Fig. 2). This work does not describe the complete orchestration process but serves as complementary methods to capture both social and technical requirements. User Stories enable the inclusion of heterogeneous actors, ranging from private to professional CCAM actors, as well as external entities such as communities or national states. They are also suitable to reveal potential conflicts and to provide a structured basis for identifying possible resolution strategies. Use Cases extend this by providing structured descriptions of the technical implementation to be developed and to further detail corresponding scenarios and low-level component requirements.

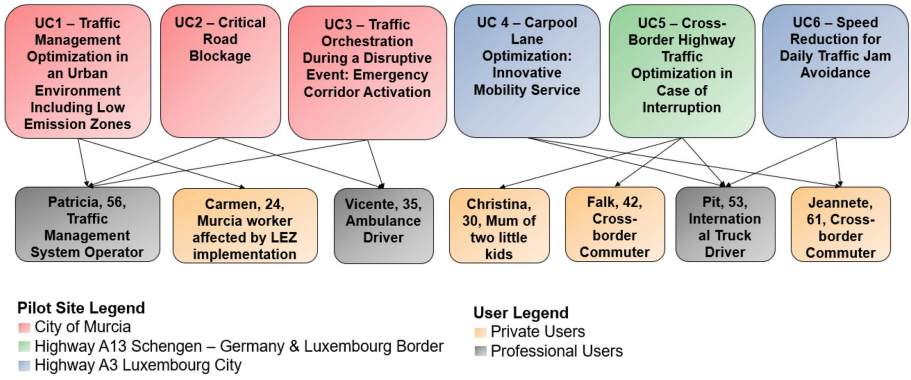


Fig. 2. CARMONY user stories, Use Cases & Pilot sites.

Two different test sites have been selected in CARMONY to deploy and validate the Orchestrator implementation: the city of Murcia (Fig. 3), where three urban Use Cases will be demonstrated, and the Luxembourg Highways A3 and A13 (Fig. 3), where three interurban Use Cases will be conducted.

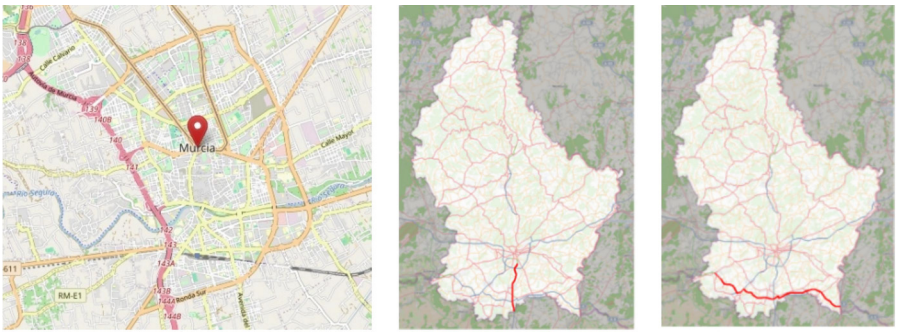


Fig. 3. CARMONY pilot sites' location. From left to right: (1) Murcia city, (2) Highway A3 in Luxembourg, (3) Highway A13 in Luxembourg.

3 Murcia Use Cases and User Stories

Murcia is the seventh-largest city in Spain with a population of about 450,000 residents. In 2024, it presented a congestion level of 21%, with an average travel time of 17 min and 16 s per 10 km – 10 s longer than in 2023 – and 43 h lost during rush hours, representing an increase of 4 h and 19 min compared to 2023 [4].

To address these challenges, Murcia was selected as one of CARMONY test sites, where the Interlinked Traffic Orchestrator will be implemented and evaluated through the conduction of three Use Cases: Traffic Management Optimization in an Urban Environment Including LEZ (UC1), Critical Road Blockage (UC2) and Traffic Orchestration During a Disruptive Event: Emergency Corridor Activation (UC3).

The complete set of solutions are deployed and tested in Murcia's real urban traffic environment. Additionally, two of the Use Cases follow a hybrid approach, meaning that the real-world demonstration will be complemented by traffic simulation.

3.1 Use Case 1: Traffic Management Optimization in an Urban Environment Including Low Emission Zones

Carmen, a 24-year-old resident of Murcia outskirts, commutes daily to the city centre, where the new LEZ regulation will restrict the entrance of her vehicle [6]. This, combined with peak hours congestion and the limited availability of public transport options, make the most viable option for her to drive to a transfer point outside the LEZ.

This Use Case aims to demonstrate how information provided by Connected Vehicles (CVs) and infrastructure contributes to traffic orchestration in urban areas under complex conditions such as LEZs. To this end, CVs will send their Origin and Destination at the beginning of their trips, along with their "vehicle profile" which shall be introduced in the CV mobile app. Based on the reported information and on LEZ restrictions, the orchestrator will provide them with optimal route recommendation.

Three possible scenarios are foreseen: (i) if the Origin and Destination are outside the LEZ, the orchestrator provides a route avoiding it; (ii) if the Origin and/or the Destination are inside the LEZ and the CV is allowed, the orchestrator suggests the best route; (iii)

if the Origin and/or the Destination are inside the LEZ and the CV is not allowed, the orchestrator suggests alternative transport options and guides CV to a convenient transfer point. The app also provides drivers with other relevant information, like traffic lights status, maximum speed or alerts for school zones.

Because of the limited availability of CVs, the physical demonstration of this Use Case will be supplemented with traffic simulation, to accurately evaluate the Orchestrator's potential impact on the city's mobility.

3.2 Use Case 2: Critical Road Blockage

Patricia is a TMS operator in Murcia. Her job consists of analysing the data collected from traffic and environmental sensors. Recently, as traffic volumes have increased, she has noticed that these sensors sometimes fail to detect traffic changes early enough [7], delaying the intervention in case of disruptions.

The goal of this Use Case is the management of a disruption and the optimization of the road network after an incident, e.g. a damaged vehicle blocking a road. Once the Orchestrator receives the incident report, CVs and Connected Automated Vehicles (CAVs) in the area are provided with updated route recommendations and indications to avoid the incident while efficiently distributing the traffic in the area.

Authorities will also receive the corresponding warning and route recommendations to reach the location of the incident when applicable. UC2 also addresses the damaged vehicle passengers' needs, providing them with alternative transportation options through a mobile phone app.

To complement the real-world demonstration, a simulation will be conducted involving a more severe disruption, such as a bus blocking the road, to test Orchestrator's performance in more challenging conditions, without compromising the safety and efficiency of the city network.

3.3 Use Case 3: Traffic Orchestration During a Disruptive Event: Emergency Corridor Activation

UC3 relates to the story of Vicente, an ambulance driver in Murcia. Currently, the city does not include an emergency corridors' network, nor provides signal priority for emergency services. As a result, combined with potential disruptions, emergency vehicles often face delays that prevent them from reaching their destination promptly.

This Use Case proves the benefits of CCAM in enhancing Traffic Orchestration during disruptive events such as the activation of an emergency. It focuses on how real-time data from CVs can support infrastructure and emergency services, in the case of a Connected Emergency Vehicle (CEV).

The main goal is the minimization of CEVs travel time while improving overall traffic efficiency and safety, thanks to the real-time warnings and dynamic route recommendations sent to other CVs and CAVs and the provision of signal priority.

The scenario starts with a notification of emergency from the Orchestrator, along with a set of predefined emergency corridors to reach it. The CEV driver selects a corridor through the CARMONY app, which notifies the Orchestrator to provide signal priority

in that route. Simultaneously, the Orchestrator sends alerts to the CVs and CAVs in the vicinity, guiding them to perform safe manoeuvres to clear the way.

The system also considers the safety of Vulnerable Road Users (VRUs). When a risk is detected, Connected VRUs receive timely warnings through the VRU app installed at their mobile phones, helping them stay safe during emergency situations.

4 Luxembourg Use Cases and User Stories

Luxembourg is a key European mobility hub, located at the crossroads of France, Germany and Belgium, with two major highway corridors: the A3 and the A13. The A3 is Luxembourg's busiest commuter route [8], connecting France with Luxembourg City, and despite recent infrastructure upgrades such as a dedicated carpool and public transport lane, congestion remains high. Luxembourg drivers lost approximately 55 h per year to congestion, and A3 hotspots such as Berchem-Gasperich accounted for around 25% of the city's delay burden [2]. The A13 [9], on the other hand, is a critical cross-border corridor near Schengen, used daily by thousands of commuters and freight vehicles traveling between Luxembourg and Germany.

To address these challenges, Luxembourg was selected as CARMONY pilot site, where the Interlinked Traffic Orchestrator will be implemented and evaluated through three interurban Use Cases: Carpool Lane Optimization (UC4), Cross-Border Highway Traffic Optimization in Case of Interruption (UC5) and Speed Reduction for Daily Traffic Jam Avoidance (UC6). The solutions will be tested in real cross-border traffic conditions on the A3 and A13, complemented with simulation environments to assess system-wide impacts and validate CCAM-enabled orchestration strategies.

4.1 Use Case 4: Carpool Lane Optimization. Innovative Mobility Services

Jeannete lives in Luxembourg City and works in France. Every morning, she drives on the A3. While the highway includes a dedicated carpool and bus lane, she cannot use it because her colleagues live in different locations. Often, she is caught in congestion while the carpool lane is underused.

This Use Case aims to demonstrate how dynamic lane management can optimize the use of the A3's carpool lane. By integrating real-time and historical traffic data, the Orchestrator regulates access through a dynamic reservation system that allows individual commuters and freight vehicles to enter the lane when capacity is available, while maintaining priority for carpooling and public transport.

Three scenarios are foreseen: (i) Non-Carpool Vehicle Access Optimization, dynamically authorizing commuters to use the carpool lane to balance traffic loads; (ii) Freight Slot Allocation, where drivers such as Pit, benefit from dedicated access to improve cross-border freight flow; and (iii) Reservation System Simulation, enabling advance booking of slots for both private and freight vehicles.

Although limited to simulation, UC4 provides a realistic environment to test dynamic lane management. The pilot assesses how optimized use of the carpool lane can improve traffic flow, increase efficiency, and support smoother cross-border mobility.

4.2 Use Case 5: Cross-Border Highway Traffic Optimization in Case of Interruption

Christina, a mother of two young children, often drives across the Luxembourg-Germany border on the A13. Road closures and long queues create stress and delays, affecting her ability to reach childcare and work on time. Similarly, Falk, commutes daily from Perl, Germany, to Luxembourg City and is frustrated by unpredictable travel times on the A13, as he experiences frequent disruptions that extend his journey. For Pit, the international truck driver, interruptions add complexity to freight routing, with risks of violating rest period regulations or delivery schedules.

The goal of this Use Case is to demonstrate real-time cross-border orchestration on the A13, improving flow and safety during both normal and disrupted conditions. Using advanced infrastructure, the Interlinked Orchestrator processes live data from roadside systems and CVs. Based on this input, it provides optimized rerouting and multimodal recommendations tailored to the users' needs.

The Orchestrator accounts for truck-specific regulations, rest periods, and border procedures while guiding commuters with efficient travel and modal choices. Benefits include reductions in congestion, travel time, fuel consumption, and accidents.

The digital LU-DE A13 corridor serves as a real-world testbed for assessing the orchestration of cross-border traffic under interruptions.

4.3 Use Case 6: Speed Reduction for Daily Traffic Jam Avoidance

Pit and Jeannete are both affected by recurring congestion on the A3 during peak hours. Stop-and-go traffic waves increase Pit's fuel consumption and delay his deliveries, while Jeannete faces a stressful and time-consuming daily commute.

This Use Case explores how speed harmonization can prevent daily traffic jams on the A3 corridor. By processing real-time and historical data, the Orchestrator coordinates traffic flow using two complementary approaches. In the Direct Communication approach, drivers receive targeted speed instructions, with system performance assessed even under partial compliance. In the Dynamic Speed Limit approach, variable speed signs display adaptive recommendations to all drivers, stabilizing the flow.

The main objective is to demonstrate how orchestrated speed reduction can prevent stop-and-go waves, enhance safety, and reduce congestion, while also investigating the penetration rate of CVs required to produce system-wide benefits.

Although implemented in simulation, this UC provides a realistic evaluation of speed harmonization strategies with impacts on commuters and freight drivers alike.

5 Conclusions and Future Work

This paper discusses the use of the CARMONY Interlinked Orchestration Framework through the six Use Cases and related user stories to be deployed in Murcia and Luxembourg. All solutions showcase the benefits that traffic orchestration can provide to different types of networks and users, not only aiming for individual needs, but also for mutual societal benefit.

The introduction of Use Cases and User Stories has proven essential for capturing the heterogeneous needs of urban and interurban actors – ranging from daily commuters like Falk to operators like Patricia. In Murcia, the focus on LEZ and emergency management showcases the Interlinked Orchestrator's ability to enhance urban resilience and sustainability. Whereas the pilots in Luxembourg highlight the potential of traffic orchestration to mitigate highway congestion.

A key contribution to this work is the shift toward non-mandatory, personalized recommendations. By balancing individual preferences with collective societal benefits, CARMONY provides a governance model that respects user autonomy while optimizing network efficiency.

With the definition of requirements, scenarios, and UML models now finalized [10], the next phase of the project will focus on the technical integration of the orchestrator components. Future efforts will involve the design and implementation of large-scale simulations and real-world demonstrations to validate the performance of the Interlinked Orchestration Framework.

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