TANGENT

NTM NEEDS ASSESSMENT AND SYSTEM REQUIREMENTS

D1.2

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Executive summary

This document aims at identifying the system requirements for the TANGENT functionalities for each case study, based on a detailed definition and description of each case study and a comprehensive consultation and engagement process with local stakeholders. In this way, it reports on the evaluation of stakeholders' needs and the analysis of the requirements of the local transport network for the architecture definition, design, and operation of TANGENT services for advanced traffic and network management.

First, this deliverable defines the process and methodology used to develop the system requirements. Chapter 0 provides a detailed description of each of the functionalities that would be tested in TANGENT, including a description of the needs and requirements of the case studies testing this functionality. Chapter 0 provides a detailed and comprehensive – yet not final – description of each of the use cases, including a description of the local context, the characterization of the local transport network, the stakeholder mapping, the traffic management strategies, the transport modelling, an overview of an impact canvas, the definition of scopes and scenarios and a description of visualization and interaction of data. Chapter 0 provides an overview of the system requirements while the final list of system requirements can be found in Annexe 1.14 at the end of this report.

As for the system requirements of the TANGENT platform, a total of 154 requirements were successfully collected, which are fundamental to guide the developments to be carried out in the coming months in work packages 2, 3, 4, 5 and 6.

Keywords

Network traffic management, stakeholder engagement, system requirements, technical and operational requirements

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List of abbreviations and acronyms

Acronym	Meaning
ACC	Automatic Cycle Counters
API	Application Program Interface
ASAP	As Soon As Possible
ATC	Automatic Traffic Counters
B2B	Business-to-Business
B2C	Business-to-Consumer
BRT	Bus Rapid Transit
CAM	Cooperative Awareness Message
CAV	Connected and Autonomous Vehicles
CCTV	Closed-circuit television
CIM	Cooperative Incident Management
COP	Common Operational Picture
CPM	Cooperative Perception Message
DENM	Decentralized Environmental Notification Message
DOA	Description of Actions
DRT	Demand Responsive Transport
EC	European Commission
FCD	Flow Car Data
GA	Grant Agreement
GM	Greater Manchester
GMP	Greater Manchester Police
GMSM	Greater Manchester SATURN Model
HGV	Heavy Good Vehicle
IoT	Internet of Things
IVI	In-Vehicle Information
KAM	Keolis Amey Metrolink
KoM	Kick-off Meeting
KPI	Key Performance Indicator

LGV	Light Goods Vehicle
LMA	Lisbon Metropolitan Area
LoS	Level of Service
NLB	Network Load Balance
NTM	Network Traffic Management
OD	Origin-Destination
OGV	Other Goods Vehicle
P&R	Park and Ride
PCU	Passenger Car Unit
PDU	Plan de Déplacements Urbains – Urban Transport Plan
PHA	Peak Hour Afternoon
PHM	Peak Hour Morning
PKI	Portuguese Key authentication Infrastructure
PT	Public Transport
PTU	Public Transport Authority
RAG	Red, Amber Green
SNLB	Smart Network Load Balance
SRN	Strategic Route Network
TBC	To Be Confirmed
TML	Transportes Metropolitanos de Lisboa – Metropolitan Transports of Lisbon
UTC	Urban Traffic Control
UTMC	Urban Traffic management and Control
UVAR	Urban Vehicle Access Regulations
VMS	Variable Message Signs
WD	Working Day
WP	Work Package

1 Introduction

1.1 Attainment of the objectives and explanation of deviations

This document aims to identify the system requirements for the TANGENT functionalities for each case study, based on a detailed definition and description of each case study and a comprehensive consultation and engagement process with local stakeholders. In this way, it reports on the evaluation of stakeholders' needs and the analysis of the requirements of the local transport network for the architecture definition, design, and operation of TANGENT services for advanced traffic and network management.

To this end, it has been essential for each case study to further identify their needs and objectives with the project, the specific implementation scenarios as well as the challenges that may be faced. Moreover, the deliverable reports on the engagement and consultation process with local stakeholders for the further identification analysis of their needs and priorities, enabling the project to derive contextual and system requirements for the TANGENT services design. This required TANGENT partners to develop further the TANGENT services and functionalities to best describe the implementation scenarios, technical requirements, and possibilities to the local stakeholders, and enable a more detailed understanding of their role and involvement.

These updates were necessary to calibrate the stakeholder engagement and to define the system requirements while ensuring the usability of the results collected, which led to a delay of several months in the production and finalization of this deliverable. These updates required further collaboration among project partners, as well as knowledge gathering and several iterative processes to be implemented to ensure the quality of the input gathered. These processes are further detailed in Chapter 0.

1.2 Intended audience

This deliverable is intended mainly for the project partners, project officers, and the public interested in the stakeholder engagement process used to define the system needs and requirements of TANGENT's services and functionalities.

1.3 Structure of the deliverable and links with other work packages/deliverables

First, this deliverable defines the process and methodology to develop the system requirements. Section 3 provides a detailed description of each of the functionalities that would be tested in TANGENT, including a description of the needs and requirements of the case studies testing this functionality. The final list of system requirements can be found in Annexe 8.

Section 4 provides a detailed and comprehensive – yet not final – description of each of the use cases, including a description of the local context, the characterization of the local transport network, the stakeholder mapping, the traffic management strategies, the transport modelling, an overview of an impact canvas, the definition of scopes and scenarios and a description of visualization and interaction of data.

This deliverable is linked to several work packages and deliverables. The following input was required from the differing following work packages:

WP7 - Input was required from case studies to further define their use case including:

- Characterization of the transport network
- Traffic management strategies

- Transport modelling
- Scope, objectives, and scenarios
- Visualization needs and data interaction

WP2/3/4/5/6 – Input was necessary to further define the possible functionalities of the TANGENT services and illustrate to the local stakeholders which functionalities could be implemented locally, to ensure that their needs would align with what is technically possible to implement within the project.

In addition, D1.2 provides input for D2.1 (WP2) and D6.1 (WP6), in particular, the definition of case studies and of specific data and system data requirements, which are necessary for the development of D2.1 and D6.1.

1.4 Brief description of the TANGENT Services

A more detailed description of each of the TANGENT services, sub-services and functionalities are available in Section 3.

2 Definition of the process & methodology

2.1 Initial Five-Stage Process

After holding the Stage 1 workshops in Lisbon, Rennes, and Manchester in March and April[1], we have identified five stages to help case studies further refine their use cases and identify their needs and objectives regarding their network traffic management. This process aimed to use the input and feedback from local stakeholders during the workshops and, with the help of the technical partners, to identify gaps and needs to be clarified.

This five-stage process is as follows:

Step 1 – Processing workshop results

- Rupprecht Consult processed the raw data from workshops and highlighted places where case studies needed to provide context and additional information. Case studies leaders acted on this in Step 3.
- Deusto and technical partners cooperated to further define the scope of the expected application and testing for each TANGENT service, and the respective questions and requirements for each case study (further detailed in Section 1.4).

Step 2 – Drafting a pre-workshop questionnaire and use a case description template

- Rupprecht Consult prepared the template and draft questionnaire with the support of technical partners in identifying key input they need from the case studies.

Step 3 – Describing use cases further

- NTUA, Rennes Metropole, A-to-Be and Carris, and TfGM filled in the use case description templates.
- ID4CAR supported and followed up with Case Study leaders to ensure their contribution.

Step 4 – Technical partner contribution and validation

- Technical partners from WP2,3,4,5 and 6 reviewed the draft questionnaire, assessed the quality of the information they needed, and identified gaps.
- Technical partners developed questions to be asked to local stakeholders regarding service requirements per functionality. All questions were gathered in the Service Requirements Templates.

Step 5 – Collection of input from stakeholders for each case study

- Local stakeholders answered a pre-workshop questionnaire.
- Local stakeholders answered some questions about the service requirements during the local workshops.
- Local stakeholders answered the rest of the questions about the service requirements in the follow-up questionnaire.

[1] Athens being a virtual case studies, there will be no stakeholder workshops for this case study

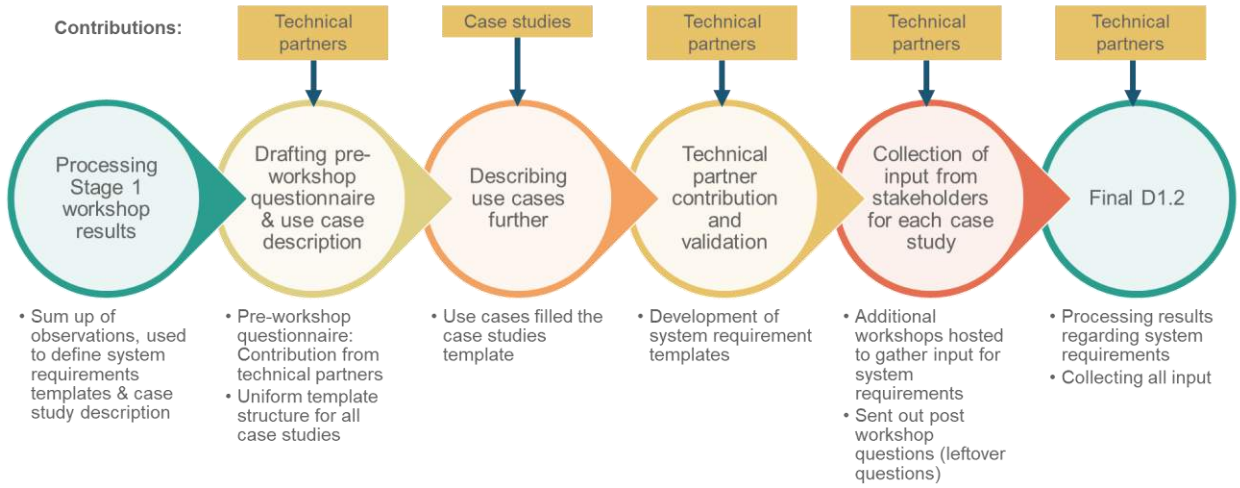

Figure 1: Representation of the methodology to develop D1.2

2.2 Development of Case study template and pre-workshop questionnaire

As a result of the Stage 1 workshops and the identification of certain specific gaps by technical partners in reviewing the results of the workshops, we have developed a use case definition template for all case studies to define their use cases following the same structure. The structure of this template included:

- Description of the local mobility context, including policy context
- Characterization of the transport network in terms of modes, data sources, and governance
- Detailed mapping of local stakeholders and their roles
- Identification of traffic management strategies
- Description of the local transport model
- Definition of the scope and scenarios of the use cases
- Definition of preferred visualization and interaction

Once completed by the case studies leaders, these use case description templates were integrated into this deliverable.

2.3 Development Service Requirements Templates

To overcome the problems, we encountered planning the TANGENT services, a methodology based on ‘User Stories’ was followed. ‘User Stories” are a tool coming from Agile methodologies for software development that aims to capture a description of a software feature from a user's perspective[2]. The first point to address was to clarify each functionality, and for what purpose each target user will use each service. That is, what expectations would each stakeholder have from each service or service functionality? This exercise helped to propose questions that could ease the definition of the user's needs and requirements.

A first initial draft of the services was then proposed, including all details stated in the Description of Actions (DoA). A detailed description of the services and sub-services (if identified) was developed, and an identification of the different stakeholder profiles using those services was proposed.

[2] https://www.techtarget.com/searchsoftwarequality/definition/user-story

Once the services were drafted, extraction of the main functionalities contained in each service was performed. In total, from 3 proposed services, 10 functionalities were identified. These functionalities were detailed with an exhaustive description and a workflow was, therefore, identified to materialize the service under a particular example.

Summing up, using the methodology of the “User Stories”, we proposed detailed descriptions of the different functionalities to cover the needs of the different types of stakeholders. This procedure helped the technical partners of the consortium to propose technical questions that could help to clarify the focus of their different tasks.

Given the large list of questions (more than 100) obtained from this exercise, the complexity of the services for non-technical stakeholders, and the fact that not all the users would be interested in knowing all the details about all the services and functionalities, it was decided to go through some of the requirements’ questions during local workshops while other questions would be covered via a post-workshop questionnaire. In addition, case study leaders were asked to identify which services and functionalities they would be interested in test in their cities, reducing the number of questions asked to local stakeholders. Further details are given below and in Chapter 4 of this document.

2.4 Workshops

An additional set of workshops have been held in June and July 2022 to identify the stakeholders' needs and service requirements and to discuss and gather responses to some of the service requirements questions defined by technical partners. The set of questions covered during the workshops was selected based on the possible discussions and interrogations they could raise among the groups of local stakeholders. The questions were selected by Rupprecht Consult and approved by Deusto. The questions not covered during the workshops were then integrated into post-workshop questions.

Before the workshops, a short questionnaire was sent to the participants, to gather additional information required by specific WPs to progress on their work. The questionnaire was made of included 25 questions distributed around the following themes:

- Profile of the participant
- Cooperative Network Traffic Management
- Traffic Network Optimisation
- Data availability and management

The choice to cover some questions in the workshops and others in follow-up questionnaires was made to ensure the continued participation and engagement of key local stakeholders in the project while ensuring to get enough responses to define the service requirements. This choice was also motivated by the need to not overwhelm local stakeholders and ensure their continuous engagement in the project, keeping in mind that the Stage 1 workshops took place in March-April 2022 and Stage 2 workshops to define the multi-actor cooperation models would take place in September-October 2022. The limited number of responses gathered to the post-workshop questionnaires confirmed the necessity to cover to the post-workshop questionnaires confirmed the necessity of covering some of the questions during workshops to get enough answers.

For the case study of Athens, as it is a virtual case study, the case study leaders have filled both the use case description templates and the system requirements templates on their own, without requiring workshops.

Additional information is available in Annexe 8.1 which includes the agenda of the workshops, the number of questions asked in the workshops and post-workshop questionnaire, and the participation levels in all questionnaires and workshops.

3 TANGENT Services requirements

This section of the report presents the Service requirements questions, which were discussed with local stakeholders during the workshop and sent to all local stakeholders after the workshop.

The table shows the functionalities being tested in each use case.

SERVICES	FUNCTIONALITY	RENNES	MANCHESTER	LISBON	ATHENS
Service 1	Current state of the TN	Y	Y	Y	N
	Future state of the TN	Y	Y	Y	Y
Service 2	CIM – Sync on-demand and PT	N	N	N	Y
	CIM – Sync traffic control and PT	Y	Y	Y	Y
	NLB – Adaptive traffic control and CAVS	N	N	N	Y
	NLB – Dynamic Congestion Pricing	N	N	N	Y
	NLB – Informing the transport passengers	Y	Y	Y	Y
Service 3	Common Operational Picture generation support tool	Y	Y	Y	Y
	Response plan generation support tool	Y	Y	N	Y
	Simulation of predefined scenarios	Y	Y	Y	Y

Table 1: The service requirements chosen by the cities for TANGENT.

3.1 Service 1 - Enhanced Information Service for Multimodal Transport Management

The idea of this service is to provide the visualization of all the data gathered in the project through a Dashboard. This Dashboard will be shown as a website. It will be selecting from different visualizations of different available data topics available, mostly map-based visualizations, and explore the visualization (pan, zoom, click on items for details, etc.). It will also support decision- making and cooperation efforts through notifications and “decision boards”.

There will also be an API that will allow services and third parties to programmatically collect accessible information from TANGENT, allowing the creation of 3rd party services like Mobility Apps, feeding existing operator websites with live unified data, etc.

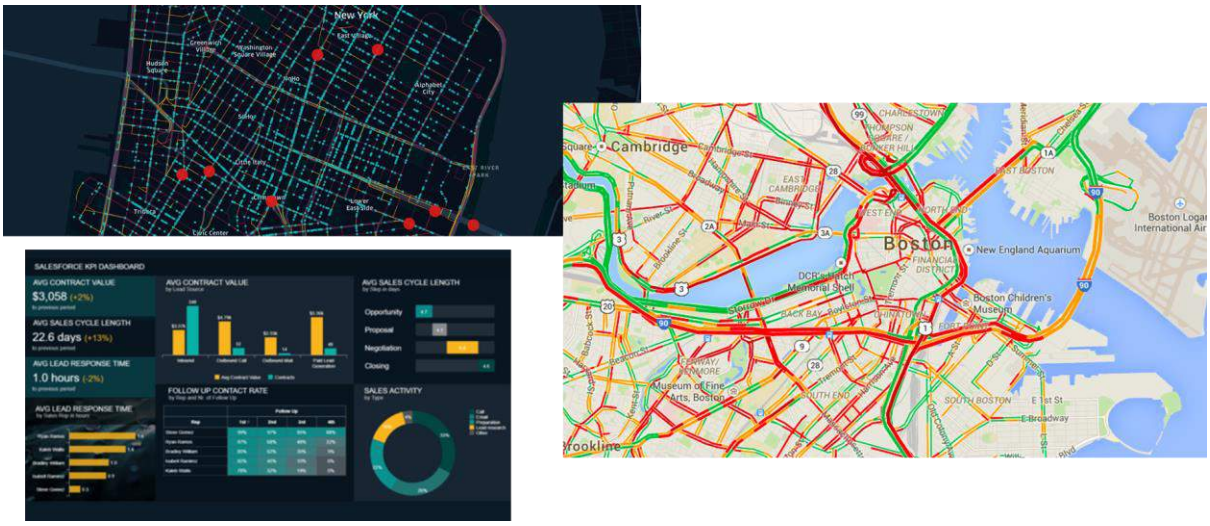

Figure 2: Examples of visualization of traffic data (source: Deusto)

3.1.1 Functionality 1 - Dashboard for The Real-Time Visualization of The Current State of The Transport Network

The objective of this functionality of TANGENT is to provide transport network managers with the most relevant traffic information of the whole transport network, according to their needs. The information, coming from different data sources, is harmonized, and shown on a map, with different granularities. The dashboard will also provide tools to visualize incidents and alerts.

3.1.1.1 Potential Stakeholders Involved

- **Infrastructure providers:** public entities (traffic and transport authorities and administrations) and private road operators can be distinguished
- Public transport operators
- **Roadside service providers:** Companies delivering traffic management activities (outsourcing from road infrastructure providers)
- **Authorities**: representing society, providing regulation and goals (represent society)

3.1.1.2 Workflow

Step 1: The user enters the credentials to access the system (e.g., login and password)

Step 2: The system provides a menu where the user can see and select, for visualisation, the different views available in the dashboard (e.g., the current status of traffic, incidents, KPIs of the performance of bus lines, etc.)

Step 3: The user selects a specific view, and the system displays that view on the device.

Step 4: This process can be repeated in case different views of the system need to be displayed on different screens for the monitoring of various simultaneous situations.

3.1.1.3 Observation of needs and requirements

All the participating cities found this functionality, its workflow, and its implementation to be very relevant and important. Some cities, however, noted that some issues might be arising at the interface between different responsibility areas of different stakeholders which might reduce the feasibility of this functionality. Challenges before and during the dashboard implementation should also be considered which could include meeting the heterogeneous expectations and needs of stakeholders, data sharing

issues (e.g., reluctance to share data), reluctance to adopt the dashboard and/or switch from the existing visualisation software, compatibility issues with the existing software/hardware of different operators etc.

Regarding the dashboard customisation, the system shall have the information pre-set for first-time users and that should be defined by the system developers accordingly. However, some cities would prefer users to be able to fully customize the dashboard based on their needs. Another choice was to have a suggestion for the dashboard based on the content on the usage of data or visualisations in the application. The cities also opted that the information available in the dashboard should be developed by the system developers accordingly but should also be available for customisation by the respective users.

The cities prefer that the information would always be available in both symbolic and satellite views, i.e., switchable according to preference.

The importance of indicators for Level of Service (LoS) and KPIs in relation to the graphical representation of traffic flows as preferred by the cities, were colour-coded pictorial representations and tables extractable to Excel. The preferred choice for visualising and monitoring the current state of the traffic was colour-coded LoS at road segments, like in Google maps and, Waze. The cities opted also for performance indicators like average hourly kilometres travelled, total average delay, etc. and graphs with travel times and delays for specific routes.

The cities would like to have the following categories of the current status of the road network to be visualised: traffic status on strategic roads/highways, traffic status in the main urban arterials, traffic status on all urban roads and traffic status in suburban areas.

For the cities, the level of importance to be given to the showing and monitoring of the real-time information on public transport would be the average delay at line level, average occupancy at line level, and global average delay.

All cities are interested in having access to the indicators for the following public transport modes indicators: Bus, Tram, and Metro services.

For the level of importance for showing and monitoring the current status of the mobility services for people and goods, Rennes voted for ride sharing (including car-pooling) whereas Lisbon and Manchester preferred Shared micro-mobility (e.g., bike-sharing, e-scooter sharing, etc.

All the cities highlighted the importance of the following incidents for this functionality:

- Traffic congestion and accidents,
- Roadworks,
- Public transport delays
- Incidents air quality issues and weather conditions,
- Road obstacles
- Emergency live events.

For the criteria of combining visualisations of different data sets, e.g., combining traffic status, bus demand status, incidents, etc the cities of Manchester and Lisbon chose all kinds of information from the data sets. Rennes opted for a specific type of information for combining the data sets as all information could not be grouped. Athens, on the other hand, opted for both the kind.

All cities are interested to see the following parameters of the current traffic status to be exposed on the API:

- Current traffic status at road segment level and their indicators
- Current traffic status of public transport performance at a specific line, both at global and vehicle level
- Current traffic status of shared mobility performance indicators and on-demand mobility performance indicators.

The cities have different viewpoints on the device they prefer for using the Dashboard. While Athens considers either not using it or using it on the laptop, Manchester and Lisbon are open to using it on large screens to mobile phones. Rennes considers using it on large screens.

The cities do not prefer to have an operator to monitor the dashboard. According to Lisbon, if operators exist, they should not respond to decision queries coming from the Dashboard but involve the concerned stakeholders to execute the necessary actions.

All the cities prefer the degree of desirability to be real-time or less than 5 minutes regarding the update frequency of the information about the current status of the traffic.

Cities prefer both low and high aggregation levels in this service. The low gives the traffic data in 100m detail and the high includes traffic data of the neighbourhood. The timings preferred for this is chosen to be less than 5 or 10 minutes.

3.1.2 Functionality 2 - Dashboard for Visualization of The Future State of The Transport Network

The objective of this functionality of TANGENT is to provide different stakeholders with information that goes beyond the current status of transport data. That is, providing the users with traffic predictions and simulations of the transport network. The visualization can be like the one displayed in Functionality 1.

3.1.2.1 Potential Stakeholders Involved

- **Infrastructure providers:** public entities (traffic and transport authorities and administrations) and private road operators can be distinguished
- **Public transport operators**
- **Roadside service providers:** Companies delivering traffic management activities (outsourcing from road infrastructure providers)
- **Service consumers**
- **Authorities**: providing regulation and goals (represent society)

3.1.2.2 Workflow

Step 1: The user enters the credentials to access the system (e.g., login and password).

Step 2: The system provides a menu to select the type of prediction among all available, and its horizon for visualisation in the dashboard (e.g., status of traffic in 30 mins, bus lines occupancy in 15 mins, etc.)

Step 3: The user selects a specific view, and the system displays that view on the device.

Step 4: This process can be repeated and contrasted against the current state of the transport network that could be displayed on different screens for the monitoring of various transport modes simultaneously.

3.1.2.3 Observation of needs and requirements

The responses received from the workshops for all the cities are summarised below:

All the participating cities found this functionality, its workflow, and its implementation to be very relevant and important.

The cities would be interested in seeing predictions of the future status of the traffic for highways, main urban arterials, and urban and interurban roads to be important.

The cities would be interested in seeing predictions of the future status of the traffic in terms of congestion intensity at the road segment level, average travel times and delays for relevant pre-defined routes and global system performance indicators (average kilometres travelled, total average delay etc.).

Cities prefer the time horizons for providing traffic predictions of the traffic state to be for 5mins and 15 mins, and to be updated every 5 minutes.

The cities would prefer to see the future state of the network in a form of a timeline to be visible for the available period of predictions, together with the option of date search to select the prediction for a specified time. Also, the data should not be live data and it should be possible to compare previous predictions to the actual live traffic for a specific time period. The cities would also prefer that the future data be presented in a different format than the visualisation of the live date (e.g., in a different colour).

The cities cited the information about the traffic indicators of average delay and average occupancy at line level as the most important for predicting the status of public transport. Other parameters include global average delay, global average occupancy level and delay at the individual vehicle level.

The indicators mentioned above could be best suited for the modes of Bus, Tram and Metro as chosen by the cities. Lisbon also chose Rail as one of the modes they find interesting.

The time horizons chosen by the cities to suggest the prediction of information about the future performance of a transport mode were 5mins, 15mins, 30mins and 60mins. The degree of desirability of update frequency for the information was chosen as less than 5mins, less than 10mins and less than 15mins.

Cities have identified in the table below available and potentially shareable historical data for road networks and public transport networks categories that could support this service.

		Athens	Lisbon	Manchester	Rennes
Road network categories	Strategic roads/highways	X	X	X	X
	Main urban arterials	X	X	X	
	All urban roads		X	X	
	Interurban areas		X	X	
Public transport service	Bus	X	X	X	X
	Metro	X		X	
	Rail		X		

Table 2: List of available historical data for the cities and their respective data providers.

Athens and Lisbon have mentioned that access restrictions for certain data may apply but could be resolved with a License Agreement or a Non-Disclosure Agreement.

3.2 Service 2 – Real-Time Traffic Management Services

Service 2 is based on the traffic and transport information provided in Service 1 - "Enhanced traffic information for multimodal transport management – Dashboard and API", TANGENT will support traffic managers at the operational/ tactical level, to optimize the overall transport network operations on a day-to-day basis.

3.2.1 Sub-service - Cooperative Incident Management

This sub-service comes into action when the mitigation of an incident's impact may require the involvement and cooperation of multiple actors (public transport operators, shared or on-demand mobility operators, traffic managers of other road networks, etc.), and aims to support and facilitate this cooperation. Following the recommendations from the C-ITS platform[3], one of the core concepts of this Cooperative Incident Management service is the so-called Common Operational Picture (COP), whose objective is to offer the involved actors, contextual information, and a standard and unified overview of the transport network situation. The COP will provide a visual interface, on top of a map, enabling the display of appropriate transport network management-related data. In this way, the COP aims at providing the involved actors with a common understanding of the transport network's current and future status. This will further enable a more coordinated, effective, and timely decision-making process among traffic managers and support public and private organizations. The main components of the COP are the following:

- Visualization of the current and expected status of the network. This will be generated using Service 1 and it will include network performance status (colour-coded KPIs and LoS) at the link or trajectory-level, via measures such as:
    - Traffic flow
    - Realized travel time
    - Estimated travel time
    - Traffic speed
- Minimum network performance allowed. Given that TANGENT will continuously monitor and assess the network performance, in terms of Level of Service (LoS), the minimum network performance or minimum LoS allows establishing a critical threshold that the different actors should ensure with their actions. This minimum LoS will depend on the nature of the incident (planned or unplanned) and the priority of the service or infrastructure affected.
- Triggering mechanisms/conditions. The trigger conditions establish the point at which the cooperation among actors and the response plans should be deployed to restore safe and flow-efficient conditions (e.g., traffic delay in the ring road is higher than 15 minutes). These triggering conditions are aimed at guaranteeing that the actions necessary to ensure the minimum LoS is activated at the appropriate time. The triggering conditions should be agreed upon by the involved actors.
- Response plans/Intervention actions. Each triggering mechanism/condition will be associated with a single or multiple response plan. These response plans will aim to orchestrate the recovery process, by combining pre-established actions from the different actors. These response plans should be also commonly agreed upon among the involved actors.

The Cooperative Incident Management sub-service has two phases:

- Planning phase: The objective of this phase is to design the COP for planned events or to facilitate the resolution of specific categories of incidents in daily operations (e.g., roadworks,

[3] https://transport.ec.europa.eu/transport-themes/intelligent-transport-systems/cooperative-connected-and-automated-mobility-ccam_en

traffic accidents in specific areas, etc.). Specifically, this phase would be carried out prior to the execution of the COP and in it, the minimum LoS, the triggering mechanisms/conditions and the response plans/intervention actions would be established and agreed upon by the different actors involved, with the help of the Service 3 functionality for supporting the COP generation. This functionality offers a structured way to agree and optimise the different elements that make up the COP thanks to the Artificial Intelligence, Transport Simulation and Multi-Criteria Decision-Making tools provided by TANGENT.

- Execution phase: this phase can only take place after the planning phase, that is, once the COP has been defined in the planning phase. Its objective is to deploy the designed/planned COP to provide a coordinated response plan among different actors for event management or incident resolution.

3.2.2 Functionality 1 - Cooperative Incident Management & Synchronisation of On-Demand and Transit Modes

The objective of this functionality of TANGENT is to foster future mobility where public transport is the backbone of the transport network and various private & public transit systems cover the first/last mile problem. Coordination of different operators can lead to the optimization of the performance of the overall network and increase their readiness in the occurrence of a planned or unplanned incident.

3.2.2.1 Potential Stakeholders Involved

- **Infrastructure providers:** public entities (traffic and transport authorities and administrations) and private road operators can be distinguished
- Public transport operators
- **Roadside service providers:** Companies delivering traffic management activities (outsourcing from road infrastructure providers)
- **Service consumers:** drivers, CAVs, fleet operators, transport operators, pedestrians, cyclists, etc.
- **Authorities**: providing regulation and goals (represent society)

3.2.2.2 Workflow

Planning phase

1. In advance, the different actors involved in a major event or in the resolution of a certain category of incidents coordinate to design the COP.
    a. Example: A DRT operator, A PT operator and a traffic manager meet to define the COP in case of unplanned events for a Demand Responsive Transport (DRT) system operating between the city centre of a relatively isolated community inside the metropolitan area and the closest railway station.
2. In this coordination process, they establish different scenarios and/or different likely incidents.
    a. Examples of incidents: an expected or unexpected closure of a particular train station, high delays in some of the lines, etc.
3. Through the previous experience and know-how of the actors involved, and with the help of the optimization and simulation functionalities of Service 3, the most appropriate coordinated response plans are defined and agreed upon for each scenario and incident.
    a. Example: adjust the operation of a DRT line to take the users to an alternative railway station or stations of alternative transport modes

Execution phase

1. The system will generate the COP, according to the planning phase, by assembling data and generating visualisations for the current and future traffic state using Service 1, as well as the minimum LoS, triggering conditions and Response plans.
2. The COP will be shared among the involved actors to create a common understanding and situational awareness of the current and future status of the transport network, as well as the response plans/intervention actions to apply to specific situations according to the triggering mechanisms/conditions.
    a. Example: Traffic managers, road operators, public transport operators and DRT operators will have access to a dashboard that displays real-time information about the current and future status of the transportation network, including private and public services, infrastructures, etc.
3. Then, the system continuously monitors the status of the network to ensure the minimum network performance allowed and detect if the triggering conditions are fulfilled or not.
    a. Example: The system detects that there is a high delay in the trains operating at the connected railway station because of a problem in the infrastructure.
4. Once the triggering conditions are fulfilled, it will apply the corresponding response plans that are defined in the COP, and it will inform the involved stakeholders of the measures to take.
    a. Example:
        i. The system notifies the DRT operator and the railway operator about this incident and the response plans agreed upon for this incident:
            1. Adjust the operation of a DRT line to take the users to the railway station in the north of the city, not affected by this problem
            2. The Railway operator adjusted slightly the schedules of the trains in the station in the north to facilitate synchronisation with the DRT line by delaying some of the trains.
        ii. The railway operator and the DRT operator notify the system that they will deploy the agreed response plan.
        iii. The railway operator and the DRT operator activate their internal processes/systems to carry out these response plans.
5. Once the incident is considered solved (transport network returns to normal status), the system will inform all involved actors which can then return to normal operations.
    a. Example:
        i. The railway operator notifies the system that the incident in the underground line is solved.
        ii. The system then, in turn, notifies the DRT operator.
        iii. The DRT operator activates their internal processes/systems to go back to the base scenario operations.
        iv. The railway operator activates its internal processes/systems to go back to the base scenario operations.

3.2.2.3 Observation of needs and requirements

Athens will be the only city testing this functionality. The responses provided below correspond to Athens' user needs and system preferences.

Athens founds this functionality to be highly relevant to their city considering its workflow to be appropriate and feasible, for both the planning and executive phase.

Athens believes that public transport providers, emergency services and authorities should be involved in this functionality of TANGENT to make the response plan possible in case of any kind of event.

Athens believes that this functionality can be appropriate for rail and metro public transport modes in priority, and then bus and tram.

Athens suggests that the Peri-urban area, the Metropolitan area, and the Rural areas at a medium distance from a city are appropriate city areas for the synchronisation of public transport and Demand Responsive transport services.

In Athens's opinion, the COP planning phase is needed both for the public transport operations and on-demand transport operations in priority for planned events, followed by the need for the COP planning phase to only be done for the public transport operations, considering that on-demand transport should be optimised in real-time.

Athens has identified the following planned events for which this functionality can be appropriate:

- Bus lines traversing the city centre are delayed due to a planned demonstration. DRT vehicles synchronize with the closest -yet unaffected by the demonstration- metro stations and transport passengers to the city centre through alternative routes.
- A major concert is planned in a peri-urban area. DRT vehicles synchronize with the closest railway stations to assure last/first-mile connection at the venue.
- A railway station is closed for renovation. DRT lines servicing the station adjust their routes and schedules and connect to the closest operational (upstream or downstream) railway stations of the same line.

In Athens' opinion, the COP planning phase is only needed to be done for the public transport operations for unplanned events. But it is also possible that there is no need for the COP planning phase as both public transport operations and on-demand transport should be optimized in real-time for unplanned events.

Athens has identified the following unplanned events for which this functionality can be appropriate:

- A wildfire necessitates the evacuation of a forested area in the metropolitan area of Athens. DTR vehicles adjust their schedule to evacuate the affected citizens. The railway schedule is adjusted to assure optimal connection to the DRT vehicles.
- A rail line is slowed down due to signalization problems. A DRT line connecting a semi-rural area to the rail corridor adjusts its schedule to assure optimal transfer between the transit modes.
- A suburban train malfunctions, leaving passengers stranded. Multiple DRT vehicles are dispatched and transport passengers to the closest to their destinations' railway stations.

When optimising the synchronization of DRT and public transport, the system should give importance priority to public transport system performance (average travel times, delays, waiting times, etc.), operational costs and the number of passengers served.

3.2.3 Functionality 2 – Cooperative Incident Management & Synchronisation of Traffic Control and Public Transport

The objective of this functionality of TANGENT is to enable the adaptation of public transport supply and traffic signalization to planned or unplanned congestion-related contingencies, leading to the optimization of the performance of the overall network.

3.2.3.1 Potential Stakeholders Involved

- **Infrastructure providers:** public entities (traffic and transport authorities and administrations) and private road operators
- **Public transport operators**

- **Roadside service providers:** Companies delivering traffic management activities (outsourcing from road infrastructure providers)
- **Service consumers:** drivers, CAVs, fleet operators, transport operators, pedestrians, cyclists, etc
- **Authorities**: providing regulation and goals (represent society)

3.2.3.2 Workflow

Planning phase

1. In advance, the different actors involved in a major event or in the resolution of a certain category of incidents coordinate to design the COP.
    - Example: Infrastructure providers, public transport operators, roadside service providers and authorities meet for planning the COP for a large event, in a peri-urban area of the city, involving many trips from the urban area to that location, by different public and private transport modes.
2. In this coordination process, they establish different scenarios and/or different likely incidents.
    - Examples of scenarios: different volumes of people attending the event
    - Examples of incidents: excessive congestion on one of the main access roads, breakdown, or problems on one of the underground lines, etc.
3. Through the previous experience and know-how of the actors involved, and with the support of the functionality of Service 3 for generating the COP and/or generating Response plans, the most appropriate coordinated response plans are defined and agreed upon for each scenario and incident.
    - Example: increased frequency of one or more bus lines serving the large event in the case of a problem in the underground line that connects the urban area with the event location.

Execution phase

- The system will generate the COP by assembling data and visualisations for the current and future traffic state using Service 1, as well as the minimum LoS, triggering conditions and Response plans commonly agreed upon among involved actors in the planning phase.
- The COP will be shared among the involved actors to create a common understanding and situational awareness of the current and future status of the transport network, as well as the response plans/intervention actions to apply to specific situations according to the triggering mechanisms/conditions.
    - Example: Traffic managers, road operators and public transport operators will have access to a dashboard that displays real-time information about the current and future status of the transportation network, including their respective services, infrastructures, etc.
- Then, the system continuously monitors the status of the network to ensure the minimum network performance allowed and detect if the triggering conditions are fulfilled or not.
    - Example: The underground operator notifies the system about a temporal failure in the underground line that connects the urban area with the event location, which will stop this service for at least 60 minutes.
- Once the triggering conditions are met, it will apply the corresponding response plans and it will inform the involved stakeholders of the measures to take.
    - Example:
        - The system notifies the traffic manager and the bus operator about this incident and the response plans agreed upon for this incident:
        - Increase in frequency and/or capacity of buses of some specific lines

        - Adaptation of traffic signals on specific corridors to better absorb the extra traffic demand caused by the higher number/size of buses
        - The bus operator and the traffic manager notify the system that they will deploy response plans 1 and 2, respectively.
        - The bus operator and the traffic manager activate their internal processes/systems to conduct these response plans.
- Once the incident is regarded as solved (transport network returns to normal status), the system will inform all involved actors, which can then return to normal operations.
    - Example:
        - The underground operator notifies the system that the incident in the underground line is solved.
        - The system then, in turn, notifies the traffic manager and bus operator.
        - The traffic manager and the bus operator activate their internal processes/systems to go back to the base scenario operations.

3.2.3.3 Observation of needs and requirements

All cities have contributed to defining their needs and the system requirements of this functionality.

This functionality is truly relevant for all cities/regions. This workflow for the planning phase of the COP is appropriate and feasible for all cities. The workflow for the execution phase of the COP is considered to be appropriate for all cities and feasible to a certain extent. Reservations have been shared by two cities in the feasibility of this functionality due to data availability (i.e., Rennes & Lisbon).

The frequency of public transport operations has been ranked with the highest importance to be optimised to define the best response plan for traffic control. Schedule, route, and vehicle capacity have ranked equally with high importance after the frequency.

The signal timings and cycles at specific corridor(s) are the most relevant parameter of cities' traffic signalization systems to be optimised to define the best response plan. It is then followed by the parametrization of SCOOT/other optimization algorithms at specific corridors, signal timings and cycles at specific areas and parametrization of SCOOT/other optimization algorithms at specific areas.

Cities believe that public transport operators and authorities, and to a certain extent infrastructure providers, should be involved in this functionality of TANGENT to make the response plan deployment possible.

When optimising the synchronisation of traffic control and public transport, cities believe that the system should give the highest importance to traffic system performance (average travel times, traffic delays, etc.) and public transport system performance (average travel times, delays, waiting times, etc.), followed by citizen acceptance (reliability, inclusion, accessibility, comfort), impacts on active modes and environmental impact (CO2, NOX, … emissions, etc.).

According to all cities, the CIM planning phase is needed both for public transport operations and traffic control in the case of planned events, and to a certain extent in the case of unplanned events (i.e., to the extent that is possible for unplanned events).

As per the cities, this functionality is appropriate for the public transport mode of Buses and Tram.

The public transport operations of schedule, frequency and route were chosen by the cities to be most feasible to be modified.

The cities would prefer to test this functionality in the events such as football games, festivals or any other social events which are planned so that the exact response could be analysed.

It is also important for the cities to test this functionality in case of unplanned events like demonstrations with road blockades, demonstrations with road blockades, meteorological calamities, storms, or heat waves. Rennes even considered testing this functionality for emergency roadworks.

3.2.4 Sub-service - Smart Network Load Balance

This sub-service aims to better balance demand and supply, optimize the performance of the overall transport network and help the network recover from incidents in which there is no need for cooperation among stakeholders.

3.2.5 Functionality 3 - Smart Network Load Balance & Adaptive Traffic Control and CAVs

The objective of this functionality of TANGENT is to leverage the new capabilities that CAVs can bring to traffic management as dynamic and automatic re-routing.

3.2.5.1 Potential Stakeholders Involved

- **Infrastructure providers:** public entities (traffic and transport authorities and administrations) and private road operators
- **Roadside service providers:** Companies delivering traffic management activities (outsourcing from road infrastructure providers)
- **Authorities**: provide regulation and goals (represent society)

3.2.5.2 Workflow

- The system will continuously monitor the status of the whole transport network (road traffic, public transport, shared-mobility/on-demand services, etc.), using the same data gathered in Service 1, to identify incidents in the transportation network.

- In case an incident is detected, TANGENT will determine whether the disruption in the transport network will be absorbed by the current traffic control and fleet management schemes.

  Example: In a future mixed traffic scenario, the system detects a severe congestion incident in the city ring road due to a vehicle breakdown.

- In case it cannot be absorbed, TANGENT will alert the traffic manager.

  Example: TANGENT determines that the current traffic control cannot absorb those delays and asks the traffic manager whether the resolution of the incident needs cooperation or not.

- With the support of TANGENT, the traffic manager will decide whether the mitigation of the incident requires multi-actor coordination/cooperation.

  Example: Using the information provided by Service 1 about the current and future status of the network, the traffic manager decides that cooperation is not needed to solve the incident.

- The system will suggest a response plan to recover from the incident.

  Example: TANGENT will suggest adaptive traffic control and CAV re-routing as the response plan more appropriate to deal with this incident and will also ask the traffic manager whether to apply this response plan or not.

- If the transport manager agrees, the response plan will be implemented.

Example:

Note: please take into consideration that this is a futuristic scenario with conventional and autonomous vehicles, not a real scenario.

- The transport manager agrees to apply adaptive traffic control and CAV re-routing as a response plan.
- The system asks the traffic manager what alternative routes he/she wants to suggest to the drivers to redirect the traffic.
- Then, the system automatically adjusts the traffic signals of the alternative routes to absorb the extra traffic (e.g., using green waves), and the existing CAVs that need to pass through the affected part of the ring road are distributed across the different alternative routes so that the overall average delay caused by the incident (including CAVs and non-CAVs) is minimized.

3.2.5.3 Observation of needs and requirements

Athens will be the only city testing this functionality. The responses provided below correspond to Athens' user needs and system preferences.

Athens founds this functionality to be highly relevant to their city considering its workflow to be appropriate and feasible.

Athens believes that infrastructure providers, authorities and roadside service providers should be involved with priority in this functionality to make the adaptations in case of any kind of event, followed by service consumers and in-car service providers.

Athens believes that this functionality is mainly appropriate for traffic congestion, traffic accidents and breakdowns/blockages, weather conditions, road obstacles and roads being obstructed by protests, mobs, etc. Emergency vehicle approaching (live event) could also be considered.

Athens considers the following parameters of the traffic signalisation system as highly relevant to be optimised for the generation of response plans for this functionality:

- Signal timings and cycles at specific corridor/s
- Parametrization of SCOOT/other optimization algorithms at specific corridors
- Parametrization of SCOOT/other optimization algorithms in specific areas
- Using Variable Message Signs to propose alternative routes to all drivers (e.g., Use 10th Av. instead of the 5th)
- Sending rerouting instructions or guidance for Connected Vehicles
- Sending rerouting instructions or guidance for Autonomous Vehicles
- Fleet allocation, meaning routes and schedules for CAV fleets
- Size of CAV fleets

Athens considers traffic system performance as an essential criterion in deciding the optimal response plan to apply, followed by the operational costs and citizens' acceptance.

3.2.6 Functionality 4 - Smart Network Load Balance & Dynamic Congestion Pricing

The objective of this functionality is to explore dynamic congestion pricing. This is a powerful control tool to balance demand and supply, help the system recover from minor or severe incidents and provide price incentives to use alternative travel modes.

3.2.6.1 Potential Stakeholders Involved

- **Infrastructure providers:** public entities (traffic and transport authorities and administrations) and private road operators
- **Roadside service providers:** Companies delivering traffic management activities (outsourcing from road infrastructure providers)
- **Service consumers**
- **Authorities**: providing regulation and goals (represent society)

3.2.6.2 Workflow

1. The system will continuously monitor the status of the whole transport network (road traffic, public transport, shared-mobility/on-demand services, etc.), using the same data gathered in Service 1, to identify incidents in the transportation network.
2. In case an incident is detected, TANGENT will determine whether the disruption in the transport network will be absorbed by the current traffic control and fleet management schemes.

   Example: The system predicts anomalous non-recurrent traffic congestion in the city centre in the next 2 hours.

3. In case it cannot be absorbed, TANGENT will alert the traffic manager.

   Example: TANGENT determines that the current traffic control and public transport operations cannot absorb those delays and asks the traffic manager whether the resolution of the incident needs cooperation or not.

4. With the support of TANGENT, the traffic manager will decide whether the mitigation of the incident requires multi-actor coordination/cooperation.

   Example: Using the information provided by Service 1 about the current and future status of the network, the traffic manager, or the authority in charge of managing TANGENT, decides that cooperation is not needed to solve the incident.

5. The system will suggest a response plan to recover from the incident.

   Example: TANGENT will suggest changing the dynamic congestion pricing scheme as the response plan that is more appropriate to deal with this incident and will also ask the traffic manager whether to apply this response plan or not.

6. If the transport manager agrees, the response plan will be implemented.

   Example:

   i. The transport manager agrees to apply the changes to the dynamic pricing scheme as a response plan.
   ii. TANGENT will suggest a set of alternative congestion pricing schemes and the zones that should be affected by the new pricing scheme to steer users towards different transport modes or uncongested road axes.
   iii. The traffic manager then will decide which one is more suitable for the current incident, according to his/her experience.
   iv. After that, it will launch the internal processes required in his/her department to apply the new dynamic congestion pricing scheme.

3.2.6.3 Observation of needs and requirements

Athens will be the only city testing this functionality. Lisbon wanted this functionality to be tested virtually as a simulation only. The results below would summarise the choices for both Athens and Lisbon.

Athens found this functionality to be highly relevant to their city considering its workflow to be appropriate and feasible. Athens ranks lower in the feasibility of the functionality's implementation. Whereas for Lisbon, this functionality and its implementation were both appropriate and feasible, in a virtual testing environment. The workflow of the functionality got a lesser rank from them.

The infrastructure providers, service consumers and authorities should be involved in this functionality to make adaptations in case of any events.

Athens believes that this functionality is appropriate for traffic congestion, air quality issues and noise pollution issues, followed by public transport excessive delays and emergency vehicles approaching. Lisbon, on the other hand, opted for traffic congestion, public transport excessive delays, air quality issues followed by road obstacles, noise pollution and traffic breakdowns.

Athens is interested in all zone-based, distance-based, and congestion-based dynamic congestion pricing schemes to improve traffic management in urban areas. These schemes are defined as follows:

- Zone-based (Zone-based pricing, including cordon and area pricing. Involves charges to drive within or into a congested area within a city. Since this type of project involves placing new tolls on multiple existing free roads, it is politically more challenging to be implemented than other types of projects).
- Distance-based (Distance-based pricing schemes levy congestion toll in terms of the distance travelled by drivers, either linearly or nonlinearly).
- Congestion-based (Distance-based pricing schemes levy congestion toll in terms of the total time delay incurred by drivers, either linearly or nonlinearly. The objective is to incentivize the use of less congested roads

Athens believes that the distanced-based scheme might be the dynamic congestion pricing scheme with the most citizen acceptance.

When deciding what dynamic response pricing scheme to apply as a response plan, the system should first give importance to the traffic system performance, then to the public transport system performance, the environmental impact, the operational costs, and the public acceptance.

Lisbon opted for Zone-based pricing as they thought it would be optimal for the citizens.

3.2.7 Functionality 5- Smart Network Load Balance & Informing the Transport Passengers

The objective of this functionality is to inform users, using different channels (e.g., vehicular communication, variable messaging panels, etc.), about incidents and the possible actions they can take to nudge them to routes, modes of transport, services, etc. that allow for the rebalancing of the transport network.

3.2.7.1 Potential Stakeholders Involved

- **Infrastructure providers:** public entities (traffic and transport authorities and administrations) and private road operators
- Public transport operators
- **Content service providers**: most dominant private parties involved in traffic management data exchange at this moment. These services provide their navigation based on a combination of their monitoring and use of publicly provided open data (e.g., TomTom, Google Maps)
- **In-car service providers**: systems where the driver submits his destination to the in-car device and expects to be advised on the best routing

- **Roadside service providers:** Companies delivering traffic management activities (outsourcing from road infrastructure providers)
- **Service consumers**: drivers, CAVs, fleet operators, transport operators, pedestrians, cyclists, etc
- **Authorities**: providing regulation and goals (represent society)

3.2.7.2 Workflow

- The system will continuously monitor the status of the whole transport network (road traffic, public transport, shared-mobility/on-demand services, etc.), using the same data gathered in Service 1, to identify incidents in the transportation network.
- In case an incident is detected, TANGENT will determine whether the disruption in the transport network will be absorbed by the current traffic control and fleet management schemes.

  Example: The system detects a non-recurrent high delay in one or various public transport lines and increasing traffic congestion in a specific area of the city due to the unexpected deviation from a protest demonstration.

- In case it cannot be absorbed, TANGENT will alert the traffic manager.

  Example: TANGENT determines that the current traffic control and public transport operations cannot absorb those delays and asks the traffic manager whether the resolution of the incident needs cooperation or not.

- With the support of TANGENT, the traffic manager will decide whether the mitigation of the incident requires multi-actor coordination/cooperation.

  Example: Using the information provided by Service 1 about the current and future status of the network, the traffic manager, or the authority in charge of managing TANGENT, decides that cooperation is not needed to solve the incident.

- The system will suggest a response plan to recover from the incident.

  Example: TANGENT will suggest informing transport passengers and content service providers as the response plan is more appropriate to deal with this incident and will also ask the traffic manager whether to apply this response plan or not.

- If the transport manager agrees, the response plan will be implemented.

  Example:

  - The transport manager agrees to inform transport passengers and content service providers.
  - TANGENT will show a form to the traffic manager to complete relevant information about the incident that will be shared with the passengers and content service providers (e.g., for public transport: line, section, station, area, reason, severity, etc.; for road traffic: incident type, cause, etc.). The transport manager fills and submits the form.
  - Subsequently, TANGENT will expose in a standardized format (e.g., SIRI Situation Exchange for PT incident information and DATEX II Situation Publication for road traffic) through its public API, the information provided by the transport manager and other information calculated using the data gathered (e.g., traffic trend, PT delay trend, etc.).
  - Transport operators, content service providers and other stakeholders subscribed to this information service, will receive this notification and act accordingly (e.g., informing their users about the incident, recommending alternative lines, transport modes, routes, etc.).

This includes the traffic manager's communication channels (e.g., Variable Message Signals, Social network profiles, C-ITS, etc.)

3.2.7.3 Observation of needs and requirements

The responses obtained are listed to get a better understanding of the needs and requirements.

The relevancy of this functionality with its implementation is of utmost importance to all the cities. Also, the workflow of this functionality was found to be highly appropriate and feasible by all of them.

The cities chose the stakeholders like public transport operators and Infrastructure providers to be amongst the interested to subscribe to this service. The other relevant stakeholders include Content service providers, In-car service providers followed Roadside service providers and Service consumers.

This functionality was found to be very much appropriate by the cities for the resolution of incidents like traffic congestion, excessive delays in public transport, traffic accidents and blockages. Incidents like a breakdown of vehicles in public transport mode, different kinds of road obstacles and weather conditions were also found to be significantly appropriate by the cities.

The appropriate communication channels for disseminating the information of this service, as chosen by the cities, include road variable message signs, applications from other content service providers like Google maps, and Waze, then importance was also given to variable message signs within the public transport network, audio announcements in the public transport and in-car alerts.

For public transport, the elements like Section, Station, and Area were found considerably relevant by the cities when disseminating the information provided by this service.

For information to be disseminated by this service, the cities chose elements like the type of situations, planned resolution and suggested actions to be more significant compared to cause, severity and Areas affected.

3.3 Service 3 - Transport Network Optimization for Transport Authorities

This service aims to support decision-makers at the strategic and tactical level for producing policies or response plans that contribute to optimizing the performance of the network, including dynamic transport network management and transport supply optimization.

3.3.1 Functionality 1 – Common Operational Picture Generation Support Tool

The objective of this functionality is to support stakeholders in the generation and definition of the different components of the Common Operational Picture for those incidents or events that require cooperation. For this purpose, TANGENT will make use of simulation and transport modelling technologies, Artificial Intelligence based optimisation, and arbitration models for consensus generation. Following the recommendations from the C-ITS platform[4], the so-called Common Operational Picture (COP), aims at offering the involved actors contextual information, and a standard and unified overview of the transport network situation. The COP has been detailed in Sub-Service Cooperative Incident Management from Service 2.

[4] https://transport.ec.europa.eu/transport-themes/intelligent-transport-systems/cooperative-connected-and-automated-mobility-ccam_en

3.3.1.1 Potential Stakeholders Involved

- **Infrastructure providers:** public entities (traffic and transport authorities and administrations) and private road operators
- **Public transport operators**
- **Roadside service providers:** Companies delivering traffic management activities (outsourcing from road infrastructure providers)
- **Service consumers**
- **Authorities**: providing regulation and goals (represent society)

3.3.1.2 Workflow

1. Prior to the generation of the COP, the actor(s) involved in its generation must perform the following actions:
    a. Design and calibrate a transport model for the scenario(s) for which they wish to develop the response plan (e.g., adverse weather conditions, big events, etc.). The simulation of the scenarios to design and evaluate various response plans to be further optimised. For the generation of the transport models, the involved actors can use transport simulation software such as Aimsun, Next, Visum, Vissim, etc. Furthermore, they may need support from internal or external transport modeller teams/departments.
    b. Define the minimum Level of Service LoS that the public authorities want to ensure. This minimum LoS can be defined by one or more thresholds (e.g., a maximum delay of 25 mins in traffic at a specific road section, maximum frequency of 20 minutes in a public transport line/service, etc.). To do this, for each of the thresholds that define the minimum LoS the user should set aspects such as:
        i. Mode of transport: e.g., road transport, bus, metro, etc.
        ii. Transport network element: road section, public transport line, etc.
        iii. Indicator to be considered as LoS
        iv. LoS threshold
    c. Achieve consensus among all actors, on the triggering conditions that will launch the response plans that will ensure the fulfilment of the minimum LoS. Each triggering condition is defined by the following elements:
        i. Mode of transport: e.g., road transport, bus, metro, etc.
        ii. Transport network element: road section, public transport line, etc.
        iii. Condition: e.g., delay > 10 mins, failure in PT line, average speed < 50% of free-flow speed, etc.
    d. Consensual among all actors, the response plans to apply to each triggering condition.

    Example: Due to flood risk forecasts caused by a heavy accumulation of rainfall in a few hours, the different actors involved in the mobility of the city, coordinated by the urban transport authority, decide to elaborate a COP to coordinate response plans in different situations depending on the amount of rainfall.

    In collaboration with the national meteorological agency, three possible scenarios are foreseen for three different levels of precipitation: 50 - 75 litres/m3 per hour, 75-100 litres/m3 per hour, and 100-125 litres/m3 per hour.

    As this is a medium-risk scenario, the minimum Level of Service is defined by the following thresholds:

    1. Threshold 1: mode of transport -> road traffic; TN element -> city's ring road; Indicator -> traffic delay; Threshold -> "< 25 mins"
    2. Threshold 2: mode of transport -> bus; TN element -> lines providing access to the city centre; Indicator -> delay; Threshold -> "< 30 mins"

The consensual triggering conditions among all actors are as follows:

1. Triggering condition 1: mode of transport -> road traffic; TN element -> city's ring road; Condition-> traffic delay > 15 mins
2. Triggering condition 2: mode of transport -> bus; TN element -> lines providing access to the city centre; Condition -> delay > 15 mins
3. Triggering condition 3: mode of transport -> bus; TN element -> lines providing access to the city centre; Condition -> delay > 25 mins

The response plans agreed upon for each triggering condition are the following:

1. For triggering condition 1 -> "Informing transport passengers"
2. For triggering condition 2 -> "Informing transport passengers" and "Synchronization of traffic control and public transport".
3. For triggering condition 3 -> "Informing transport passengers" and "Synchronization of DRT and public transport"

2. The scenarios and transport models developed in the previous step should result in one or more transport model configuration file(s) to be used to design the COP. These configuration files should be generated using the same transport simulation software as above.

   Example: For each scenario, they define which areas will be flooded and which infrastructure and transport modes would be affected. Based on this information, they prepare different configuration files for the Aimsun Next transport simulator.

3. The authority in charge of the coordination of the COP would use the TANGENT platform to generate the COP.

   Example: The user logins into the TANGENT platform and navigates to the Service 3 -> COP generation support tool

4. The system would ask the user to define the name and other information of the COP to be generated, as well as the account of the actors that will be involved in the COP.
5. It would then ask the user to define the minimum Level of Service to be set. To do this, the system asks for information on the mode of transport for which you want to set it (e.g., road transport, bus, metro, etc.), and on the area, road, line, section on which you want to define it
6. It would then ask the user to define the minimum Level of Service (LoS). To do this, for each of the thresholds that define the minimum LoS the user should set their components:
   a. Mode of transport
   b. Transport network element
   c. Indicator to be considered as LoS
   d. LoS threshold

   Example: The user enters the thresholds defined in the example of Step 1.

7. Once the minimum LoS is defined, the system asks the user to define the triggering conditions. To do so, a menu appears to establish the conditions and establish the following elements:
   a. Mode of transport
   b. Transport network element
   c. Condition

   Example: The user enters the triggering conditions defined in the example of Step 1.

8. Once the triggering conditions are defined, for each triggering condition, the system asks the user to define the next elements:
    a. Which response plan/s to apply from the following six options:
        i. Informing transport passengers
        ii. Dynamic congestion pricing
        iii. Adaptive traffic control with CAVs
        iv. Synchronization of traffic control and public transport
        v. Synchronization of DRT with public transport
        vi. Other (definition entered manually)
    b. The configuration setup for the optimisation of the response plan.
    c. The transport simulator configuration file defines the scenario on which to optimise the selected response plans.

    Example: For each triggering condition, the user selects the response plans indicated in Step 1, defines all the parameters of the optimization process, and uploads the corresponding transport simulator configuration file.

9. The system asks the user if he/she wants to launch the optimisation of the response plans and the optimisation will be done iteratively with the simulations of the selected response plans.
10. The system launches in the background the optimisation of the response plans using Artificial Intelligence techniques and shows on the screen how the optimisation is progressing. This process can take a long time (several hours).
11. Once the optimisation is finished, the system will notify the user and will show the results of the optimisation of the different response plans.
12. For each of the selected conditions and response plans the system will show the different solutions found and also different KPIs for each of them.

    Example: For each of the defined conditions, and for each of the response plans that require optimisation, the system displays the best options it has found, as well as different graphs and KPIs regarding the evolution of the incident recovery process, environmental impact, operational costs, etc.

13. The system asks the user if he/she wants to use multi-criteria and consensus decision methods for the final response plans to be applied for each of the trigger conditions.
14. If yes, the system would launch the multi-criteria decision and consensus application and go to the following step (15). If not, the user would manually select the response plans for the trigger condition and go to the last step (17).
15. The multi-criteria and consensus decision system would ask for information and preferences from each of the actors involved in the COP design that was defined in Step 4.

    Example: Given that many response plans involve cooperation between several agents (e.g., traffic managers and public/private transport operators), and, in many cases, seek a trade-off between increased operational costs and service level, they decide to use the multi-criteria and consensus decision system to estimate which specific response plans lead to a better trade-off.

16. The system would launch the multi-criteria decision and consensus process and it would determine the best response plan for each trigger condition according to the preferences and trade-offs between the different actors.

    Example: Considering the preferences and trade-offs between the different agents, the system establishes that the ideal response plans for each condition are as follows:

i. Condition 2: Increase frequency on alternative lines to those affected and change the configuration of traffic signals on roads where affected lines pass to reduce delay.
ii. Condition 3: Use of DRT services to take users whose lines are most affected to other, less affected public transport lines.

17. The system asks the user if he/she wants to finalize and save the COP. If so, it is registered in the TANGENT database for later application.

3.3.1.3 Observation of needs and requirements

This functionality was highly relevant for the cities and the workflow of this functionality was also considered appropriate and feasible for the cities of Athens, Lisbon, and Manchester, although its implementation of it received lower ranks from the cities.

As chosen by the cities, the types of Stakeholders involved in this functionality include Infrastructure providers, public transport operators and Authorities.

The cities opted for scenarios, triggering Conditions and response plans to be the relevant elements to be defined for COP.

Elements of COP to be consensual among all involved stakeholders chosen by the cities to be important were scenarios, triggering conditions and Response plans.

The cities of Lisbon, Athens and Manchester chose the element Mode of Transport as relevant to be defined to establish each threshold defining the Minimum Service Level. They gave importance to other elements like transport network elements, e.g., road section, public transport line, LoS indicators and threshold. Rennes opted only for Mode of transport (road, bus, metro etc).

Athens voted that this functionality could be appropriate for planned events like football matches, music concerts, social demonstrations, and weather events like thunderstorms and roadworks. For Rennes, the relevancy relevance was for football matches, music concerts and other public events.

Manchester, on the other hand, gave some other examples like congestion on specific road segments, capacity on each line when threshold capacity is reached, and road closures where this functionality could be appropriate.

This functionality was found to be appropriate by the cities in case of unplanned events like meteorological disasters, unforeseen traffic incidents, floods and storms events, unusual congestion and emergency and evacuation alerts.

In optimising response plans for each scenario, the importance given by the system from the cities' point of view were traffic system performance (average travel times, traffic delays etc.), public transport system performance (delays, waiting times etc.), environmental impacts, road safety, operational costs, and citizens acceptance.

For the frequency of cooperating with other Stakeholders for the levels of control relating to transport network management (Strategic, Tactical, Operational), Athens and Lisbon chose Strategic (e.g. for establishing the long-term environmental vision of the public transport network), while Manchester opted for Tactical (e.g. for traffic light synchronisation) and Rennes chose Operational (e.g. for the mitigation of planned or unplanned disruptions in the network) as their most important choices. Lisbon opted for Operational, and Manchester opted for Strategic also as their second choice.

Current cooperation between Stakeholders, concerning transport network management, as opted by the cities as more frequent were with Transport authorities, Central & regional government, and government agencies, Public or private transport service operators and Traffic managers.

The cities voted both for Formal exchanges such as formal meetings, workshops etc. and Informal exchanges such as informal meetings, informal phone, or email exchanges, etc. regarding the structure of the cooperative activities with other stakeholders.

For the decision-making process during the cooperation activity, the cities ranked consensus-based decision-making where the stakeholders work together to find a mutually acceptable solution and decisions are made by agreement. They also gave importance to other kinds of decision-making processes where decisions are made at the highest level and stakeholders are then communicated or stakeholders also opine to express their views and provide input.

The ways the information to be shared between stakeholders during cooperation activities, as chosen by the cities were Data portals, Reporting, Data exchanges during formal meetings and informal exchanges.

The cities agreed to cooperate with other public and private transport providers for improving overall system performance.

The cities were willing to cooperate in the fields of Data exchange, Common payment systems and Integrated transport services.

Circumstances under which the cities are willing to cooperate are listed below:

- The cooperation should benefit my company
- The companies/organisations must not have conflicting interests
- The profit allocation should be fair
- The operational costs allocation should be fair
- Data sharing must be transparent
- Access to decision-making should be fair

Times expected for the optimisation process of the response plan to expect the most appropriate response plan found important by the cities were 2 hours, 5 hours, and 10 and 15 hours.

3.3.2 Functionality 2 – Response Plan Generation Support Tool

The objective of this functionality is to support stakeholders in the generation of response plans for the resolution of incidents (e.g., Dynamic Congestion Pricing, Adaptive Traffic Control and CAVs). For this purpose, TANGENT will make use of simulation and transport modelling technologies, Artificial Intelligence based optimisation, and arbitration models for consensus generation.

3.3.2.1 Potential Stakeholders Involved

- **Infrastructure providers**: public entities (traffic and transport authorities and administrations) and private road operators
- **Public transport operators**
- **Roadside service providers**: Companies delivering traffic management activities (outsourcing from road infrastructure providers)
- **Authorities**: providing regulation and goals (represent society)

3.3.2.2 Workflow

1. Before the generation of the response plan, transport authorities involved in its generation must design and calibrate a transport model for the scenario(s) for which they wish to develop the response plan.

   Example: Due to relevant roadworks in the city in the upcoming weeks, the traffic in one area of the city will be severely affected and a new response plan is needed.

2. The scenarios and models developed in the previous step should result in one or more transport model configuration file(s) to be used to design the response plan.

   Example: In collaboration with the City Council and the company in charge of the roadworks, the modelling department of the transport management authority elaborates different configuration files for the different stages of the road work.

3. The traffic manager or the person in charge would use the TANGENT platform to generate the response plans.

   Example: The user logins into the TANGENT platform and navigates to the Service 3 -> Response plan generation tool.

4. The system would ask the user to define the name and other information of the scenario for which the response plan will be generated.

5. The system asks him/her to define which response plan/s he/she wants to study for that trigger condition from the following six options:

   - Informing transport passengers
   - Dynamic congestion pricing
   - Adaptive traffic control with CAVs
   - Synchronization of traffic control and public transport
   - Synchronization of DRT with public transport
   - Other

6. The user chooses an option, and then the system takes the user to a screen where he/she can define the configuration elements of the optimisation of the response plan.

7. Once these parameters have been entered, the user saves them, and the system asks if he/she wants to define the optimisation of another type of response plan.

8. If so, the system returns to step 5). If not, the system continues with step 9).

9. Next, the system asks the user to upload the transport simulator configuration file that defines the scenario on which to optimise the previous response plans.

10. The system asks the user whether he/she wants to define the optimization of the response plans for another scenario. If so, the system returns to step 4), or else the system goes to step 11).

    Example: The user defines as response plans for the first stage of the roadworks, the response plans “Informing transport passengers” and “Dynamic congestion pricing” to reduce traffic in that part of the city. For the second stage of the roadworks, the user selects the response plans “Informing transport passengers”, “Dynamic Congestion Pricing” (for the same reason as in scenario 1), and “Adaptive traffic control and CAVs” because some bus lines are affected.

11. The system asks the user if he/she wants to launch the optimisation of the response plans for the different scenarios.
12. The system launches in the background the optimisation of the response plans using Artificial Intelligence techniques and shows on-screen how the optimisation is progressing. This process can take a long time (with an order of magnitude of hours).
13. Once the optimisation is finished, the system will notify the user and will show the results of the optimisation of the different response plans.

    Example: For each of the defined scenarios, and for each of the response plans that require optimisation, the system displays the best options it has found, as well as different graphs and KPIs regarding the evolution of the incident recovery process, environmental impact, operational costs, etc.

14. The system asks the user if he/she wants to consider the generation of the response plan as finished and to save it. If so, it is registered in the TANGENT database for further application.

3.3.2.3 Observation of needs and requirements

The functionality of this service is regarded by Athens and Manchester as of high importance with its implementation being also feasible in their region. The workflow for this functionality is highly appropriate and feasible. Rennes and Lisbon did not choose this functionality as a part of this project.

Important Stakeholders involved in this functionality for Athens were Infrastructure providers, public transport operators and Roadside service providers, whereas for Manchester were public transport authorities. They also gave importance to others like Infrastructure providers, Emergency services, Service consumers etc.

Appropriate planned events for this functionality that were important to both the cities included events like football matches, expositions, and music concerts. Also, social protests resulting in road blockages, disruptions in public transit services, weather warnings like thunderstorms, heavy rainfall and roadworks were given importance by the cities.

For the choice of unplanned events to fit this functionality the cities chose appropriate unplanned events like unplanned social protests resulting in disruption, unforeseen weather events and unpredicted road closures.

In optimising the response plan, the criteria that the system should give importance to include a wide range namely Traffic system performance (average travel times, traffic delays, etc.), Environmental impact (CO2, NOX and other emissions), Operational costs, Citizens' acceptance, Road safety and impact on active modes. Importance was also given to the public transport performances like travel times, delays, waiting times and Operational costs.

The time expected for the optimisation process of the response plans to expect the most appropriate response plan mainly was 2 hours and 5 hours. Second in ranking came 7 hours, 10 hours, and 15 hours.

3.3.3 Functionality 3 – Simulation of Pre-Defined Scenarios for Transport Network Management

The objective of this functionality is to support stakeholders in the simulation of scenarios related to transport network management that is not linked to the optimization of response plans or the Common Operational Picture. Some examples are the following:

- Extending the usage of automated shuttles to other areas in the city (e.g., business parks, hospitals),

- Impact of different CAV penetration rates on the network performance considering adaptive signal control and dynamic routing,
- Introducing bike-sharing as an alternative travel choice,
- Altering the public transport service frequencies,
- Implementing dynamic congestion pricing in the city centre/congested areas.

For this purpose, TANGENT will make use of optimization and simulation technologies.

3.3.3.1 Potential Stakeholders Involved

- **Infrastructure providers:** public entities (traffic and transport authorities and administrations) and private road operators
- **Public transport operators**
- **Roadside service providers:** Companies delivering traffic management activities (outsourcing from road infrastructure providers)
- **Service consumers**
- **Authorities**: providing regulation and goals (represent society)

3.3.3.2 Workflow

1. Prior to the simulation of the scenario, the transport modellers must design and calibrate a transport model(s) for the scenario(s) they wish to assess.

   Example: the transport authority wants to assess the impact of traffic management of different CAV penetration rates on the network performance considering adaptive signal control and dynamic routing.

2. The traffic manager or the person in charge would use the TANGENT platform to simulate the results of the scenario.

   Example: The user logins into the TANGENT platform and navigates to Service 3 -> Simulation of pre-defined scenarios

3. The system would ask the user to define the name and other information about the scenario to be evaluated.
4. Next, the system asks the user to upload the transport simulator configuration file that defines the scenario to simulate.
5. The user uploads this file and then the system asks if he/she wants to define another scenario.
6. If yes, the system will take the user to step 3 If not, the system proceeds to step 7).

   Example: the user uploads one configuration file for each penetration rate to be evaluated.

7. The system asks the user if he/she wants to simulate the scenario.
8. The system launches in the background the simulation of the scenario and shows on the screen how the simulation is progressing. This process can take a long time (from minutes to hours).
9. Once the simulation is finished, the system will notify the user and will show the results and different KPIs.

   Example: The system will display different graphs and KPIs for each of the scenarios defined.

10. The system asks the user if he/she wants to export the results of the simulation to different pre-defined formats (e.g., Excel, pdf, etc).

3.3.3.3 Observation of needs and requirements

The functionality of service 3 was chosen by the cities of Athens, Lisbon, and Manchester. Athens regarded this functionality as of high importance with its implementation also feasible in their region. The workflow for this functionality is highly appropriate and feasible. For Manchester, both the functionality and its workability got not have so much importance. Lisbon, on the other hand, provided mixed reactions giving high importance to the relevancy of the functionality and its workability but less to the implementation of the functionality and feasibility of its workability.

From the Stakeholders' interest point of view, the cities vouched for stakeholders like Infrastructure providers, public transport operators and Authorities.

Appropriate scenarios for this functionality described by the cities were Dynamic Congestion Pricing, Increased Bus frequencies, Understanding CAV penetrations on network performance, music concerts, and Festivals.

The time expected for the simulation of pre-defined scenarios to expect the most appropriate response plans, found important by the cities, were 2 hours, 5 hours, and 7 hours. Athens also gave importance to other timings such as 10 hours, 15 hours, 24 hours, 48 hours, and more than 48 hours.

The importance of the categories of indicators when displaying the results of the simulation was given to Traffic system performance (average travel times, traffic delays, etc.), Public transport system performance (average travel times, delays, waiting times, etc.), Environmental impact (CO2, NOX, … emissions, etc.), Operational costs, Road safety and Citizen's acceptance (reliability, inclusion, accessibility, equity, comfort)

Scenarios appropriate for this functionality as described by Athens included:

- Introduction of a congestion pricing scheme in the inner ring of Athens to curb the emissions and congestion in the city centre.

Scenarios to be implemented virtually as described by Lisbon and Manchester were:

- Implementation of congestion pricing schemes
- Redirecting vehicles to unoccupied off-street/on-street parking places
- Redirecting vehicles to park & Ride locations
- What if the capacity and frequency of Buses are increased

4 Use case description

This section details the description of each of the use cases along a common structure, highlighting:

- The local context
- The characterization of the transport network
- Stakeholder mapping
- Traffic Management Strategies
- Transport Modelling
- Impact canvas per TANGENT services
- Visualisation and interaction

4.1 Lisbon

4.1.1 Local context

4.1.1.1 Mobility and policy context

The Lisbon Metropolitan Area (LMA) has 3 million inhabitants with 5 million person-trips each day. Of these, the majority are estimated to be made by car (56%) and public transport modal share only amounts for a quarter of the trips. There is a significant movement of commuters towards the city of Lisbon, which lies at the geographical centre of the metropolitan area and is its main commercial, business, and administrative hub. 370.000 cars are estimated to enter the city on a typical day (for reference, the city has approximately 500.000 inhabitants). This creates significant pressure on the road network, leading to congestion, and brings relevant impacts to the city, notably in terms of urban space management (e.g., parking capacity is scarce), environmental aspects (e.g., noise, air pollution), and other social aspects (e.g., road safety).

Accordingly, the city of Lisbon is committed to rebalancing its modal split. Whilst passenger cars account for 46% of trips per day (a share that is already lower than the average for the wider metropolitan area), the objective is to reduce this number to 34% by 2030, which would imply shifting approximately 150.000 people per day from their cars into sustainable modes (i.e., cycling, walking and other micromobility modes, public transport). To achieve this goal Lisbon is foreseeing an investment in more attractive public transport, e.g., through the renewal of bus fleets or the expansion of metro and tram networks, more accessible public transport, e.g., offering free access to people older than 65 y/o and students up until the age of 23 y/o, increasing the offer of cycling infrastructure, etc.

The plan Lisbon Strategic Vision 2030 presents a proposal for future mobility in the city, pointing out guidelines for operational success, namely the reinforcement and/or evolution of 5 transport networks (pedestrian, public transport, road, cycle, and interfaces).

However, it is also clear that addressing the challenges posed by traffic and mobility in the city of Lisbon implies a wider perspective that, considers, the whole LMA. This is where the TANGENT project can contribute to the achievement of these objectives. The metropolis of Lisbon has a large deployment of big network devices and C-ITS infrastructure on the main motorways accessing Lisbon city CRIL (also denominated IC17 or A36), IC19 (also denominated A37), N6 (also denominated Marginal), A1, A2, A5, CREL (also denominated IC18 or A9), and A12. There are also traffic counters and classifiers, variable message panels, speed, and lane control sign information, for exchanging data with the transport network. This information is of paramount importance to optimize the functioning of the mobility system and provide incentives to shift to more sustainable modes of transport.

TANGENT will use information from existing systems and integrate data from public transport operators to enhance traffic information service for multimodal transport management, pilot real-time Traffic

Management Services, and/or assess transport network optimization for Transport Authorities. TANGENT particularly will consider the use of AVs and new C-ITS technologies for improving information flows and look at the transport system's reaction outside of normal conditions, e.g., during major events or disruptions.

The Case Study pilot will either focus on the Oriental part of Lisbon, with available transport modes: Bus, Metro, Train, Cycling, Motorways (A1 and Vasco da Gama Bridge), where the largest city events are usually located: Web summit (60k people/day, 4 days, annual, next ed: 2023), Rock in Rio - *music festival* (~80k people/day, 4 days, bi-annual, next ed: 2024), Jornadas Mundiais da Juventude - *youth festival* (~1 million people for the 5 days of the event, single occurrence, 2023) or at the Western part of Lisbon, where information from the A5 and A9/CREL Motorways accessing the city can be combined with data from the operation of public transports: Bus, Train, Cycling and Tram line 15. The annual NOS Alive *music festival* occurs every year at the Passeio Marítimo de Algés (~50k people/day, 3 days, annual, next ed: 2023) and is one of the possible planned events to be studied (although not strictly located at Lisbon city perimeter).

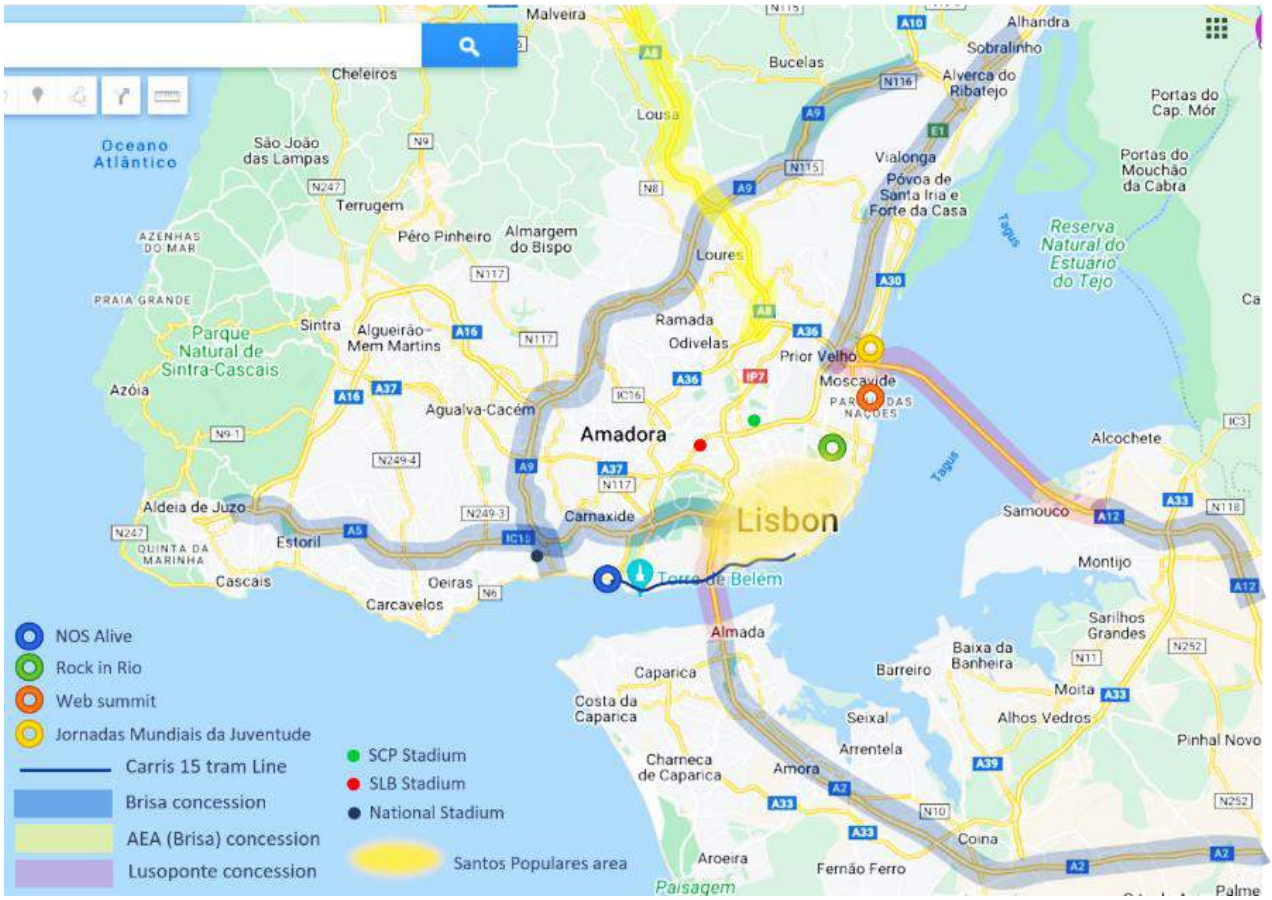

Figure 3: Map of the city of Lisbon showing the locations of different city events, under consideration for the Case Study, with the main tolled motorways entering the city and tram line 15.

4.1.1.2 Introduction of new travel alternatives

The aim of TANGENT in Lisbon is not to provide new mobility services. The focus will be on the collection, analysis, and provision of information, and on the use of modelling techniques to support decision-making.

4.1.2 Characterisation of the transport network in terms of modes, data sources, and governance

4.1.2.1 Transport Modes and Services

The Lisbon Metropolitan Area is served by extensive road and rail networks, including tram and light rail services, and there is widespread availability of shared mobility services within the city of Lisbon and some of the other main Municipalities. Accordingly, we can summarise the following transport modes and services.

Cars (and Motorcycles)

There is a dense road network, including several motorways: two ring roads constitute the main metropolitan structural road infrastructure the - external ring road CREL and the internal ring road CRIL. CRIL is almost coincident with the limit of Lisbon City whilst CREL distances approximately 10 km from Lisbon. The main radial motorways (A1, A5, and A8) in the North bank of the Tagus River) are charged toll fees until they cross with CREL (which is also tolled) and the radial motorways on the South bank (A2 and A12) are charged with toll fees until the bridges (which are also tolled). So, in summary, there is no congestion charging or similar in Lisbon, but toll charges apply up until the entry into the city for those coming from the South bank of the river and, for the North bank, at approximately 10 km of Lisbon.

There are some traffic restrictions in the city of Lisbon, particularly associated with a Low Emissions Zone that covers the historical centre and the financial centre. Moreover, on-street parking is paid for in most of the territory of the Lisbon Municipality and substantial areas of the surrounding Municipalities (Cascais, Oeiras, Sintra, Loures, etc). So, costs of commuting by car in Lisbon shall include fuel and other vehicle costs, parking costs and road tolls (when applicable).

In terms of mobility services for passenger cars, several applications provide traffic information in real-time (Google Maps, Waze, TomTom). There are also Variable Message Signs on most motorways and entry roads to the city and at several points within Lisbon's urban roads network.

Finally, there are several operators of ride-hailing solutions in the LMA (e.g., UBER, BOLT) and some offer car-sharing services. Taxis are regulated at the Municipality level and have an extensive presence across the LMA. There is also motorcycle- sharing services, especially in Lisbon.

Public Transport

There is an extensive offer of Public Transport across the LMA. Four main rail lines are providing suburban rail services (Cascais, Sintra, Azambuja, and Setúbal lines), which connect Lisbon with a Metro network that covers most of the Central, North, and Eastern parts of the city. The historical centre of the city and Western neighbourhoods are served by tram lines. In the South Bank of Lisbon (Almada) there is also a Light Rail network. There are also frequent ferry services connecting the South bank cities and Lisbon, which offer a quick access route into central Lisbon.

As for bus services, these are present throughout the LMA. The Cities of Lisbon, Cascais and Barreiro operate their bus services, but all other 15 Municipalities tender their bus services through the public company and authority 'Transportes Metropolitanos de Lisboa' (TML). In addition to managing these tenders (organised in four lots), TML manages the integrated ticketing system, which offers the possibility to access fully integrated monthly and occasional tickets.

Over the last few years, there were important changes in Public Transport affordability in the LMA. In 2019 a new set of monthly tickets were introduced, offering a 40 € monthly ticket for the entire public transport network in the LMA (and a 30€ ticket for all public transport within a single municipality), irrespective of mode or operator. In addition, the monthly ticket is free for children up to the age of 14 y/o and there are 60% discounts for people aged 65 or older. There are also discounts for students and

beneficiaries of other social benefits. Cascais has already introduced free public transport for all residents and from 2022 the residents in Lisbon aged up to 24 y/o or 65 and older are also entitled to free public transport.

Several apps support navigation on the public transport system. These are mostly from private providers (Google Maps, Moovit, etc) and are based on information provided by the operators on open data portals using the GTFS standard. For some operators' information is provided in real-time (i.e., GTFS real-time), which allows these apps to provide accurate information about the operation of the system. Some of the apps also use their own customers' data to provide real-time information about delays or disruptions.

Walking, cycling and other active modes

There was a substantial investment in the walking and cycling networks across most of the LMA. This has led to increased safety for pedestrians and growth in the modal share for bicycles and scooters. In particular, the city of Lisbon has seen over the last decade a sharp increase in cycling infrastructure which fuelled increased use of bicycles as a mode of transport and the emergence of numerous electric bike and scooter sharing schemes (GIRA, UBER, BOLT, LIME, …). No real-time data are available for these modes.

The main stakeholders for mobility in Lisbon are:

Infrastructure managers: Infraestruturas de Portugal (for interurban roads, motorways, and rail networks), Brisa (for most tolled motorways) and Lusoponte (for the two tolled bridges over the Tagus River). The Municipalities are responsible for the management of the local road networks, including traffic control and information systems.

Parking infrastructure: most cities have established companies to manage their on-street parking systems (and some off-street facilities), including EMEL in Lisbon, CascaisPróxima in Cascais or Loures Parques in Loures. SABA and Empark are private companies that are relevant players in the off-street parking market (other smaller players also exist).

Public Transport Authorities: The Municipalities are the authorities for road public transport in their cities, with 15 of 18 having delegated the responsibilities for bus network authority in the Metropolitan Area (which controls TML). The Metropolitan Area is also responsible for all public transport tariffs. The Portuguese Government is the Authority for Metro, Ferry, and Rail services.

Public Transport Operators: The main players are CP – Comboios de Portugal (State-owned), Metro de Lisboa (State-owned), Fertagus (Private concession) and Metro Sul do Tejo (Private concession) for rail and light rail systems; TML as bus concessionaire in 15 municipalities and CARRIS in Lisbon (which also operates the tram network). Transtejo is responsible for the ferries.

Other mobility providers: EMEL is responsible for Lisbon's station-based bike sharing system; There are several floating bike and scooter sharing providers in Lisbon as well as ride-hailing apps. Via Verde (part of Brisa) provides its customers with an efficient payment solution to mobility-related services such as motorway tolls, off and on-parking, gas service stations, EV charging, ferries, and others.

Other service providers: Google Maps, Waze, TomTom and Moovit are examples of information suppliers for mobility in Lisbon, covering all modes of transport.

4.1.2.2 Transport Infrastructure

The C-ITS network installed at LMA (Figure 4) is a level 0 security roadside infrastructure, fully capable of emitting and receiving C-ITS messages (DENMs, CAMs, CPMs, IVIs, etc), which at present, can only

be received by field test vehicles, with dedicated communication equipment. Several new vehicle models are reaching the roads with C-ITS technology embedded but operating at production security level 2 and not enabled. Nevertheless, few vehicle models have it enabled and are emitting, so one can obtain Floating Car Data (FCD), e.g., instant vehicle speed, location, and events, e.g., congestion, from them. To have fully bilateral communications between connected vehicles and the C-ITS network, the Portuguese Key authentication Infrastructure (PKI) needs to evolve from level 0 to level 2, which is expected to happen in the next couple of years. The following provides details about the different locations of C-ITS Roadside Stations in and around Lisbon with different colours representing different ownerships. Stations from A-to-Be and BCR are controlled by Brissa. IP, CML and GMV are other third-party authorities handling the stations but are external to this project TANGENT.

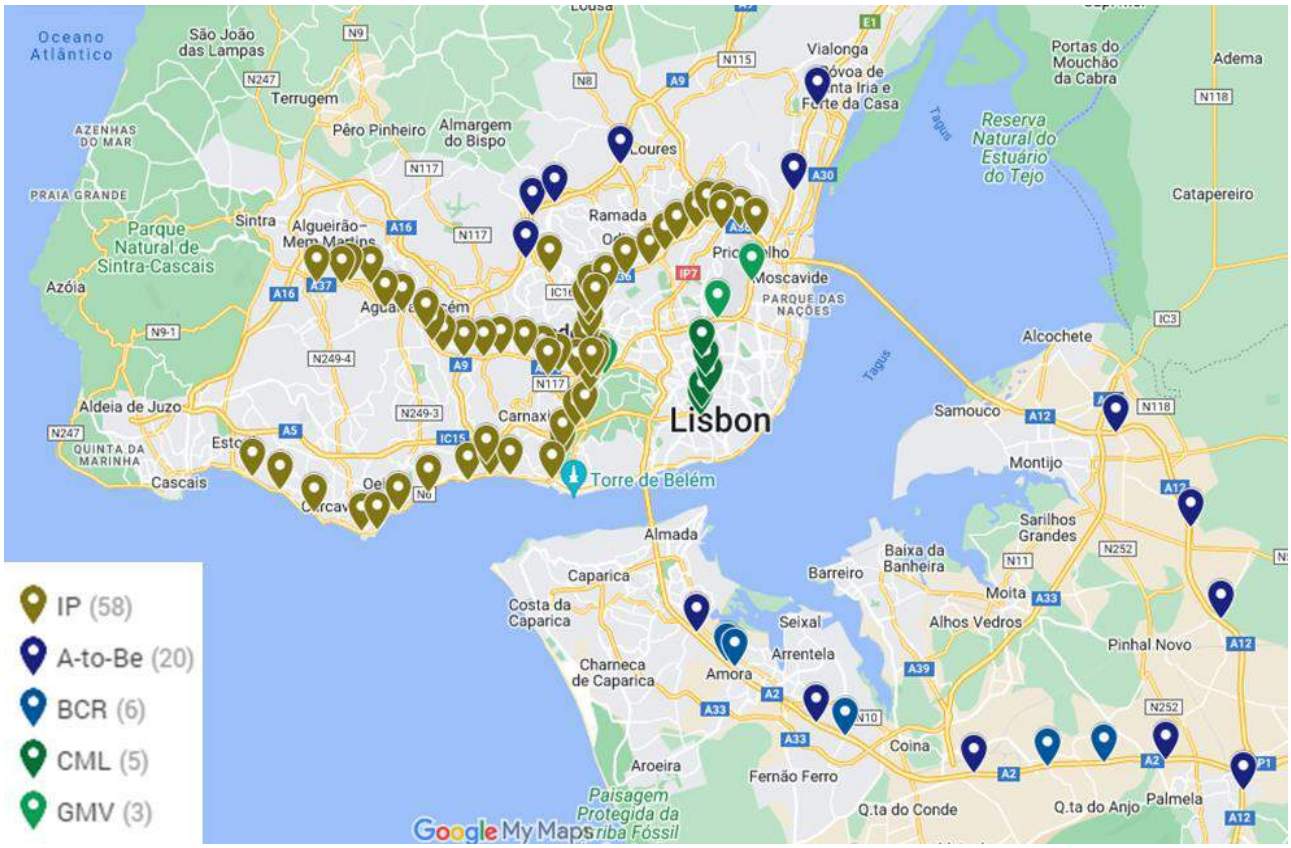

Figure 4: C-ITS Roadside Station locations in and around Lisbon. Different colours represent different ownerships. Brisa controls A-to-Be's and BCR stations

Traffic Light System

EMEL is implementing the Lisbon Smart Mobility System (SIM.Lx), which will allow enhanced management of the traffic light network, centralising all traffic lights in Lisbon and, through the introduction of a predictive component, allow the creation, in real-time, of special traffic light plans for programmed actions, namely: the closing of roads for special events, and plans for random events, such as accidents/one-off incidents, circulation of emergency vehicles, as there will be the ability to anticipate the different traffic scenarios likely to create congestion situations.

Currently, the traffic light network in Lisbon brings together 547 traffic light intersections (set of controlled equipment), of which only 138 are connected to the central GERTRUDE system, a revolutionary system in the 80s when it was introduced in the city, but which has not followed the evolving nature of urban mobility, and which is clearly out of step with today's needs.

Motorway Sensors

The main tolled motorways accessing Lisbon city (A1, A2, A5, A8, A9, and A12) have a large deployment of traffic counters and classifiers, variable message panels or signs (VMS) speed, and lane control sign information for gathering data and informing the users of the transport network.

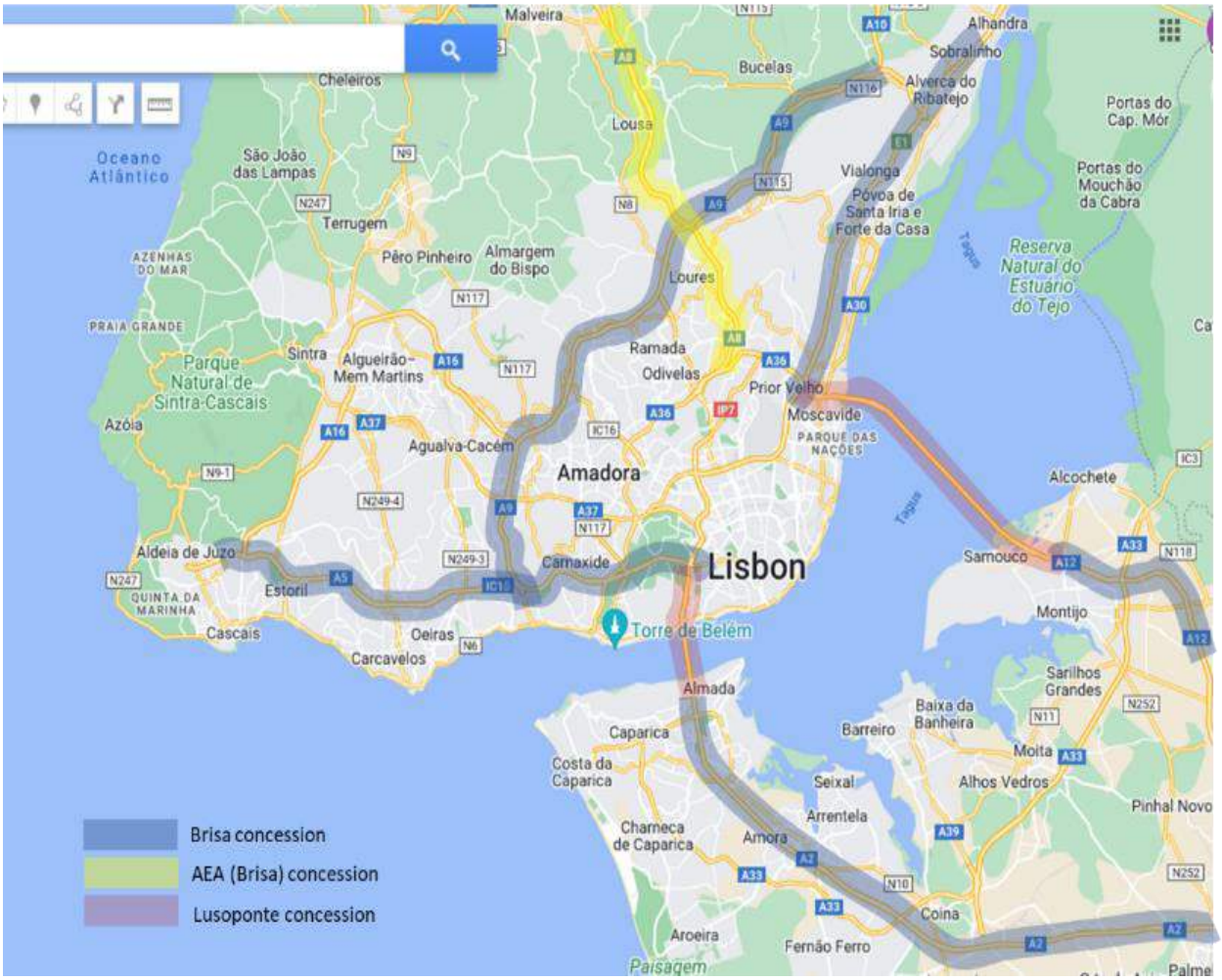

Figure 5: Concessions of the main tolled motorways and bridges accessing Lisbon, to which TANGENT can directly access data through Brisa.

Local network Sensors

Within the city of Lisbon, there are several data collection points to monitor traffic. These are mostly related to the traffic lights control system, operated by the city traffic department and/or Lisbon's mobility company EMEL. At the moment, and this may evolve in the next few months, traffic counts are available for approximately 100 road sections. In some cases, other data may be available, e.g., queues, speeds, etc.

4.1.2.3 Overview of data sources

Further information on data sources can be found in the deliverable D2.1 will develop this further.

4.1.2.4 Characterisation of governance

The Lisbon mobility ecosystem is characterised by the presence of numerous organisations and a complex governance structure. There is a distribution of responsibilities between various Government

levels – Municipalities, Metropolitan areas, and National Government – and the coexistence of public and private mobility operators. For example, on the road network the local roads are managed by the Municipalities, often including roads from a high service level that encompass the connection of different Municipalities. The main interurban roads and non-tolled motorways of regional character (without toll) are managed by the National Level, which delegates responsibilities to the public company Infraestruturas de Portugal. Some motorways and bridges are then operated under a concession by private companies or companies with private capital.

As for Public Transport, the picture is even more fragmented. Rail and ferry systems are regulated at the National level. They are mostly operated by public companies, although the Lisbon/Setúbal rail axis and the light rail network in the South part of LMA are under concession to private companies. Ticketing and most bus services are managed at the level of the Metropolitan area, which is a body elected by the 18 Mayors of the LMA. Bus (and tram) services are managed and operated by the Municipalities in the case of Lisbon, Cascais and Barreiro.

Because of this fragmented framework, there is an extensive culture of collaboration across stakeholders. For example, it has not precluded the availability of integrated ticketing solutions in public transport or the use of Via Verde for road toll payments all on tolled roads irrespective of their operators. However, collaboration is always limited by the commercial interests of each part or legislation (e.g., competition law, GDPR).

4.1.3 Stakeholder mapping

This table provides an overview of the local stakeholders and their role in each of the services and functionalities.

TANGENT Sub-service	Functionality	Stakeholder type	Role	Name of the local stakeholder
TANGENT Service 1: Enhanced information service for multimodal transport management				
Real-time information	Visualise the current status of the network	Public Transport Operators	Provide supply (and desirably) demand information	CARRIS - Bus and TRAM Operator METRO LISBOA - Metropolitan operator CP - Train Operator FERTAGUS - Trans- River urban train operator TML - Interurban bus Authority
		Road Operators	Provide traffic network conditions and the current state	IP - National infrastructure for interurban roads, non-tolled motorways, and rail networks Brisa - Tolled motorways infrastructure around Lisbon Lusoponte - Tagus Bridges infrastructure NAP - National Access Point
		Content service providers	Provide traffic network conditions and the current state	Waze, TomTom, Google Maps, Bing Maps - Traffic, INRIX, Moovit (PT modes)

		Public micro-mobility operator	Provide bike sharing supply and demand	EMEL - Municipal mobility and parking company
		Parking Operators	Provide parking supply and demand	Municipal parking systems: Lisbon - EMEL Cascais - CascaisPróxima SABA, Empark and other private parking systems
Predictive Information	Visualise the future status of the network	Public Transport authorities	Provide mobility calibrated models	CML/EMEL & Carris
TANGENT Service 2: Real-time Traffic Management Services				
Smart Network Load Balance:	Informing the transport passengers	All	Provide data and models	
Cooperative Incident Management:	Synchronisation of transit and traffic	All road operators and public transport operators involved	Provide data and models and cooperate for incident management	Depending on the part of the city chosen, different road and PT operators exist
TANGENT Service 3: Transport network optimization for Transport Authorities				
COP generation		All involved in CIM and Simulated scenarios functionalities	Situation analysis, consensus decision, (possible) action implementation	
Simulation of scenarios suggested by the decision maker		All involved in the functionality of the Simulated scenario	Provide data and (possibly) available models. Provide detailed scenarios to be simulated. Define parameter configurations. Evaluate obtained response plans	What-if scenario 1 - Implementation of congestion pricing schemes: A-to-Be, Via Verde, CML, TML What-if scenario 2 - Capacity and frequency of buses are increased? CML, Carris, TML

Table 3: Lisbon Stakeholder mapping

4.1.4 Traffic Management Strategies

The relevant strategies that are relevant to the pilot for the city of Lisbon are listed below:

- Travel behaviour management (through information provided to the user)
- Dynamic congestion pricing
- Prioritising public transport
- Synchronisation of traffic and public transport

4.1.5 Transport Modelling

In the city of Lisbon, several municipal entities are developing a multi-modal traffic flow model, mapping individual transport demand and PT offer, in PTV Visum. Distinct transport modes are at different development stages:

Traffic flow model for the city (ulvs): Individual motorised transport. *Completed and calibrated for* 2019 PHM – Peak Hour Morning and PHA – Peak Hour Afternoon (from EMEL)

Details of the model are outlined below.

- Modelling level (macro, micro, etc.) - Visum = Macro
- Transport modes included (e.g., public transport, bicycles, car, trucks) - PT, Cars, Bikes
- Network supply information. Traffic/Transit control plans (e.g., for AM and PM) AM and PM peaks

There is no information at the moment on the aggregation period of the Origin-Destination matrices. Also, the model is currently being developed, as a result, there is no information about this planned update.

The bicycle flow model for the city is currently being developed by EMEL. The public transport flow model for the city includes individual motorised and public transports. It is currently being developed by Carris and is going through validation and calibration in 2022.

The considered network supply comprises:

Road Network:

- Encoded Approximately 80,000 Arcs
    - Defined Active Transport Systems
    - Defined the Hierarchical Level of the Via/Track
    - Defined the Typology of the Road
    - Defined Capacities, Speeds & Number of Vias/Tracks
    - Defined BUS corridors
- Encoded Approximately 190,000 Movements
    - Defined the Typologies of Movements
        - Definition of Active Transport Systems
        - Assignment of Traffic Light Movements (Vehicles & Pedestrians)
    - Insertion of Traffic Light Programming (PHM-WD & PHA-WD). WD stands for Working Days.
        - Validation of Programs and Respective Security Matrices.
        - Assignment of Traffic Light Groups to Previously Coded Movements.

Cycle Network:

- Cyclable Infrastructure (Unidirectional/Bidirectional Cycle Path, etc.)
- Topographic Characteristics (Quotas)
- Location of GIRA Stations

Public Transport Network:

- Routes, Trips (schedules) and Travel Starts for:
    - rail mode (CP, Metro and Fertagus), river mode (Transtejo and Soflusa)
    - road mode (Carris)

The adopted zoning system covers all national territory, with 3 levels of refinement/detail level: denser for Lisbon city area (detailed w/ #208 zones, see Figure 4) less dense at the LMA region (simplified w/ #69 zones) and macro for the remaining territory (#7).

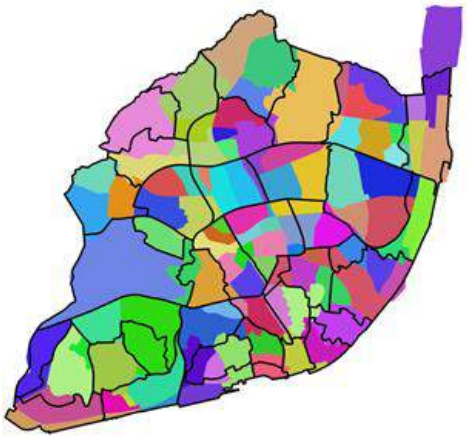

Figure 6: Different zonings for the traffic model of the Lisbon city area

For the interurban traffic motorway at A5, managed by Brisa, two academic modelling works describe the traffic flow at this city arteria: one evaluates the progressive introduction of Autonomous Vehicles (CAVs) and the other the implementation of a Dynamic Congestion Pricing scheme.

Magalhães 2022 (PhD thesis submitted) a microscopic traffic VISSIM model for the first 7km of A5, to evaluate the enhancement of road safety with the introduction of CAVs, either considering a penetration of 25% and 50%, for two use cases: shared lanes and CAV dedicated lanes. To assess their impact the following Key performance Indicators (KPIs) were calculated:

- Average Speed
- Served Demand Rate
- Average Travel Time
- Average Travel Time by Distance
- Average Delay
- Total Delay in Travel Time
- Vehicle Hours of Travel

Lombardi 2022 (PhD thesis) constructed a model for the dynamic toll pricing definition problem, using feedback control theory, for an A5 motorway 15 km segment, which has multiple access locations (Figure 7). There are no plans to update this model during TANGENT and its use for TANGENT is still under discussion.

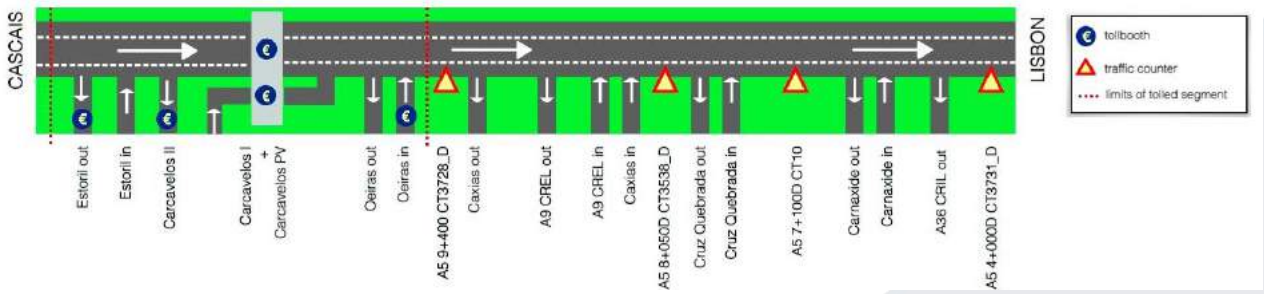

Figure 7: A5 segment schema with entries, exits, tolls and traffic counters represented.

The author presents a socio-technical study on dynamic toll pricing based on driver behaviour and traffic flow models (Figure below), with input demand calibrated using data from 2017.

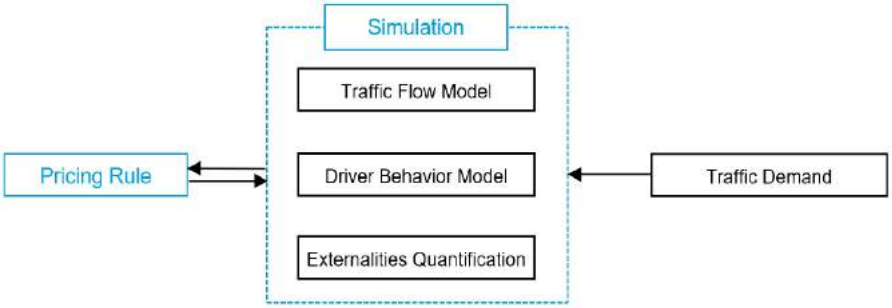

Figure 8: Socio-technical study on Dynamic toll pricing

The approach consists of a real-time closed-loop strategy where, considering a reference traffic flow state (Z_{ref}), any deviation from it (E) is fed into a price controller which determines toll prices (Π), which needs to be paid when accessing the motorway from one of the on-ramps, and which enter as inputs into the socio-technical model. The latter consists of both the driver behaviour model, which represents the driver's decision on whether to enter the motorway or not, and the traffic flow model, which captures the dynamics between the incoming traffic flows from the on-ramps (Q) and traffic density at the counters' locations, defining the system state Z.

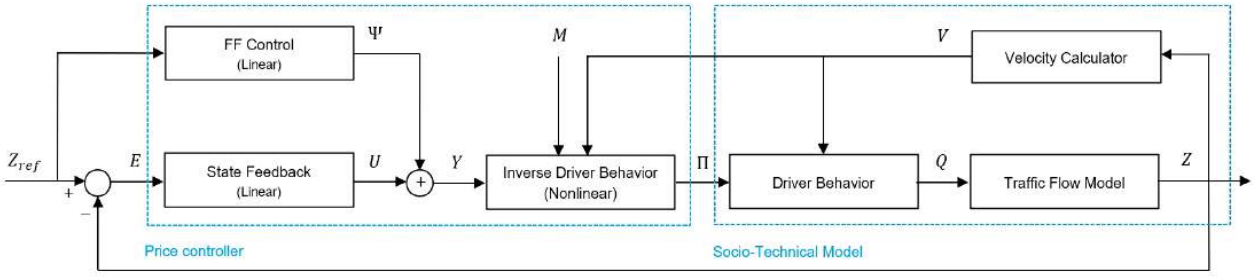

Figure 9: Dynamic Congestion Pricing Traffic flow dynamics

4.1.6 Impact canvas per TANGENT service

TANGENT Services	Objectives	Case Study Description and requirements	Target users and benefits	Expected Impact	Challenges
(1) Enhanced information service for multimodal transport management – Dashboard & API	This service is important to the city because *it*: 1a) Will provide an integrated overview of transport modes, promoting more sustainable mobility through intramodality 1b) Will provide map/traffic widgets, customised for different users' needs 1c) Will gather operators, namely interurban, potentially getting access to integrated real data 1d) Will promote consensus between actors by data sharing 1e) Will allow decision-making using data from "Silos" owned by other companies 1f) Will promote stakeholders' collaboration through data provision, model sharing and coordinated decision making 2) The information congregation achieved should leverage services 2 and 3, through the visualisation of the network status and of the outcomes of the service, with possible action/decision activation	Transport modes possibly considered *(strongly dependent on available data)*: 1) Cars (connected and conventional) 2) Taxis and on-demand car services 3) Bus 4) Tram 5) Metro 6) Trains 7) Public ferries 8) Cycling 9) Other micro-mobility services (e-scooters, motors, etc) 10)Tourist buses *Network Elements to be considered:* a) Motorways and inter-urban roads b) Urban roads c) Bus lanes d) Other physical transport via rails,	Regional authorities, Road Operators, PT Operators, and all other mobility entities that serve the city. Indirectly, through data publication, connected users (irrespective of transport mode) can also benefit from this service namely: 1) PT users 2) Car users 3) Connected transport users 4) Park & ride (P&R) users 5) Inter-urban commuters 6) Cyclists and other micro-mobility users 7) Pedestrians 8) Tourists (that although can belong to all the above categories, have a different use of the city compared to daily commuters) 9) Emergency services	- Make available traffic and mobility data for processing and modelling - Integrate data sources from multiple stakeholders - Disseminate with enough level of detail and accuracy the current and future status of the network, including incidents - Publish efficient user recommendations	- Data quality (supply, demand, dynamic, behavioural data)

TANGENT Services	Objectives	Case Study Description and requirements	Target users and benefits	Expected Impact	Challenges
		water, underground, etc.			
(2) Real-time Traffic Management Services	This service is important to the city because its implementation will allow the optimization of transport network operations in both business-as-usual scenarios and in the case of planned or unplanned events. It will *provide the necessary analytics* allowing to: 1) Coordinate urban mobility services 2) Provide a governance framework for urban and inter-urban traffic cooperation 3) Improve traffic flows and reduce traffic jams 4) Decrease urban car trips, by promoting the shift from individual cars to PT 5) Improve response to Incidents (resilience in operations) 6) Perform smart transport network balance, indicating adjustments in the offer of services, when incidents occur 7) Facilitate the focus on parking & other services, namely on schools' surroundings operation	All modes involved in the Lisbon case Study will be managed by Service 2 (Check the list of available models).	1) All connected users (irrespective of transport mode) - check the previous row list~ 2) All the stakeholders involved in the Lisbon case Study, whose modes of transportation will be managed by this Service 2. Namely: a - Traffic Managers b - Road authorities c - PT operators d - Mobility Private operators e – Micro mobility services providers	Through the sub-services of: a) Automatic Optimization of urban and interurban mobility flows by passenger recommendations b) synchronisation of urban public transport with incoming inter-urban traffic promote the following KPIs: i) 7% shift from private car to public transport ii) 10% reduction in person-hours lost due to congestion (#) iii) 10% increase in automatically managed incidents with multiple stakeholders (#) (#) by 2030	- Data availability and completeness (supply, demand, dynamic, behavioural data) - Limited optimization capabilities (e.g., system complexity, computational load) - Stakeholder engagement in creating a relevant Lisbon model - Effective dissemination of results for stakeholders to implement actions - Promotion of behavioural shift in commuters to achieve the ambitious KPIs

TANGENT Services	Objectives	Case Study Description and requirements	Target users and benefits	Expected Impact	Challenges
	[increase children's safety & use of active modes)] With Service 2 implementation we should have a tool that can perform: -Incident Management in Transports - Planned/Unplanned event handling -Handling conventional and connected vehicles with C-ITS services				
(3) Transport network optimization for Transport Authorities	This service is important to the city because it can promote: - Transport network optimization - Mobility service planning - Identify opportunities for new public transport services/lines - Situations handling optimisation, by generating different possible scenarios - Geofencing/regulation (UVAR - Urban Vehicle Access Regulations) in certain areas	All modes involved in the simulations for Transport network optimization (service 3) for the Lisbon case Study	All the stakeholders involved in the Lisbon case Study, whose modes of transportation will be simulated in Service 3 Other transport authorities, namely: Police; emergencies services, IMT, IP, ANSR.	- Obtain optimal response plans to be activated by Service 2 - Increase awareness of the impact of different policies on the transport network - Simulation of multiple traffic scenarios: (i) dynamic congestion pricing, (ii) increased PT supply that can achieve simulated KPIs of: - 5% reduction in serious injuries by 2030	- Stakeholder engagement in creating a relevant Lisbon model - Simulation representativity - Effective dissemination of results for stakeholders to implement actions - Promotion of behavioural shift in commuters to achieve the ambitious KPIs

TANGENT Services	Objectives	Case Study Description and requirements	Target users and benefits	Expected Impact	Challenges
				- 10% reduction of the Greenhouse Gas emissions by 2030 - a reduction of air pollutant emissions (at least 10%) and noise	

Table 4: Impact canvas per TANGENT services for Lisbon

4.1.7 Scope and Scenarios definition per TANGENT Services

TANGENT Service 1: Enhanced information service for multimodal transport management							
Functionality		Objectives	Scope: Virtual or Real (where?)	Baseline Scenario	Planned Event(s)	Unplanned Event(s)	Future Scenario(s)
Real-time information	Visualise the current status of the network	real-time representation of: - traffic conditions - Public transport modes - Incidents - Planned or unplanned events	Real	The current status of the network is displayed on the Dashboard	One or more of the following major events (Web Summit, Jornadas Mundiais da Juventude, Rock in Rio, NOS Alive) (if feasible) or other planned events available for demo: sports (major football match); cultural event (Santos Populares), etc	Some unplanned events available for demo: PT mode strike; Major storm or other weather calamities, road accident, etc	-
Predictive Information	Visualise the future status of the network	Multiple future time horizons for the real-time representation: - Traffic conditions - Public transport modes - Incidents - Planned or unplanned events information	Real	Optimization of interurban flows on motorways by speed and route recommendations	One or more of the following major events (Web Summit, Jornadas da Juventude, Rock in Rio, NOS Alive) or other planned event: sports (major football match); cultural (Santos Populares)	PT mode strike	The scenario depicted from the Lisbon Strategic Vision 2030 of future enhanced transport networks

Table 5: Scope and Scenarios definition for Service 1 for Lisbon

TANGENT Service 2: Real-time Traffic Management Services							
Functionality		**Objectives**	**Scope: Virtual or Real (where?)**	**Baseline Scenario**	**Planned Event(s)**	**Unplanned Event(s)**	**Future Scenario(s)**
Smart Network Load Balance	Informing the transport passengers	Promote a balanced and fluid transport network by publishing passenger recommendations and information about disruptive incidents, and planned or unplanned events. Disseminate it through the entire transport network (C-ITS and PMV messages, PT information channels, and other relevant channels). This information should include: -current status of the network -decided response plan	Virtual	Automatic Optimization of urban and interurban mobility flows based on average journey speed across modes. Through: - PT information channels: mode choice recommendations and other relevant info - C-ITS/PMV: route and speed recommendations and other relevant info	One of the following major events (Web summit, Jornadas da Juventude, Rock in Rio, NOS Alive) or other planned event: sports (major football match) or cultural (Santos Populares)	PT mode strike; Major storm or other weather calamities	Lisbon Strategic Vision 2030 future networks
Cooperative Incident Management	Synchronisation of transit and traffic	Assessment of the impacts of transit and traffic synchronisation, public transit efficiency for different modes and traffic conditions in selected axes/areas	Virtual	Optimization of urban and interurban mobility flows with cooperative management for the	One of the following major events (Web summit, Jornadas da Juventude,	PT mode strike	Lisbon Strategic Vision 2030 future networks

TANGENT Service 2: Real-time Traffic Management Services							
Functionality		**Objectives**	**Scope: Virtual or Real (where?)**	**Baseline Scenario**	**Planned Event(s)**	**Unplanned Event(s)**	**Future Scenario(s)**
		Cooperation between stakeholders for incident management Evaluation of behaviour and mode changes		synchronisation between transit and traffic, through simulated mobility scenarios for different times of day and under various conditions.	Rock in Rio, NOS Alive) or other planned event: sports (major football match) or cultural (Santos Populares)		

Table 6: Scope and Scenarios definition for Service 2 for Lisbon

TANGENT Service 3 Transport network optimization for Transport							
Functionality		**Objectives**	**Scope: Virtual or Real (where?)**	**Baseline Scenario**	**Planned Event(s)**	**Unplanned Event(s)**	**Future Scenario(s)**
Simulation of scenarios suggested by the decision maker	What-if scenario 1: Implementation of congestion pricing schemes	Evaluate the introduction of congestion pricing schemes, in the inter-urban city accesses, for the reduction of congestion (and emissions) in the city centre	Virtual	Simulated urban and interurban traffic flows around and into the city centre, with and without the introduction of congestion pricing schemes at the inter-urban city access	Congestion due to planned roadworks	Major congestion due to road accidents	Lisbon Strategic Vision 2030 future networks
	What-if scenario 2: Capacity and frequency of buses are increased?	Evaluate traffic patterns w/ the introduction of extra buses either in the urban, interurban and/or interurban city accesses. Assess changes in the modal split because of increased bus availability	Virtual	Simulated urban and inter-urban traffic flows around and into the city centre, comparing the current installed and reinforced bus capacities, possibly in different geographical areas of the city	One of the following major events (Web summit, Jornadas Mundias da Juventude, Rock in Rio, NOS Alive) or other planned event: sports (major football match) or cultural (Santos Populares)	PT mode strike	Lisbon Strategic Vision 2030 future networks

Table 7: Scope and Scenarios definition for Service 2 for Lisbon

4.1.8 Visualisation and Interaction

	Description of the data	Potential Data Source/Stakeholder	Expected Visualisation
Data from Existing Data-sources	Real-time traffic flows (from counters, radars, etc.)	Waze, TomTom, Google Maps, Bing Maps - Traffic, INRIX, Moovit (for PT modes)	Visualisation of traffic flows updated with new data every 5 minutes (desirable – to be confirmed the minimum possible update interval from external providers). Traffic flows states are represented by a red to green colour shade over the roads. Lanes and directions are distinguishable when zooming in.
	Real-time C-ITS data (CFD from detected cars)	A-to-Be	Visualisation of traffic flow from connected cars, updated with new data every 5 minutes. Hoovering over a connected vehicle the provided CFD data can be visualized.
	Aggregated traffic data (from counters installed on highways and urban roads and from tolling transactions)	Highway data: Brisa (through ViaVerde); Urban data: through EMEL	Visualisation of traffic flows updated with the lowest available aggregation period. Traffic flows states are represented by a red to green colour shade over the roads. Lanes and directions are distinguishable when zooming in. The date they refer to should be identified.
	Bus and Tram real-time supply	Carris	Live bus real-time location in a geographic map. Updated live. Some details about each bus when passing the mouse over the bus icon.
	Bus and Tram occupancy level	Carris	Information about the average occupancy of buses and trams per line, stop and period. This information is still being worked on internally at CARRIS so it is not possible to provide details (e.g. periods of the day) but we can confirm it will not be real-time.

	Description of the data	Potential Data Source/Stakeholder	Expected Visualisation
	PT modes supply: station locations and timetables	Carris (Bus and Tram); Metro, Fertagus (Train), CP (Train) - All Open Data	Scheduled supply is located on geographic maps. Some details (frequency and vehicle paths) about each mode when passing the mouse over the mode icon.
Process information	**Journey time for routes**	Waze, TomTom, Google Maps, Bing Maps - Traffic, INRIX, Moovit (PT modes)	Visualisation of journey time updated with new data updated every 5 minutes (desirable).
	Events, incidents, and roadworks	Portuguese NAP, and/or Datex II end point from Brisa (through A-to-Be), complemented with incidents reported from connected vehicles (using the same Datex II endpoint)	Location of real-time traffic events/incidents mapped, with polygon delimitation of its extent. Hovering over with the mouse results in the display of relevant information (e.g., type of event, authority to respond, response plan).
	Road equipment positions	Highway data: Brisa (through ViaVerde); Urban data: through EMEL – Open Data	Positions of traffic loops, cameras, traffic lights, other sensors, lot devices, etc. are depicted as objects on a geographical map. Hovering over with the mouse results in the display of relevant information available (e.g., traffic counts, traffic light scheduling etc.).
	KPI and LoS Dashboard		Key Performance Indicator (KPI) and Level of Service (LoS) display infographic box, w/ parameter customization module for KPI and LoS definition

	Description of the data	Potential Data Source/Stakeholder	Expected Visualisation
Process Information	Planned events and incidents		Design module for planned events, with some parametrization of the network (closing streets, adding transport supply, etc) and with visualisation of its influence polygon on the available maps.
	Resolution of an incident		Documentation of the resolution. The applied response plan is rated for its mitigatory capacity. All ratings of event-response plan pairs are documented for future reference and analysis. Successful response plans are automatically proposed in similar future incidents/events. Stakeholders can also attach comments for future reference.
Predictive Information	Multiple future time horizons from Tangent predictions' module	WP4	Available predictions are visible on top of the real transport network Live map, with clear formatting to identify them as projections. Confidence level or similar metrics should be presented with data prediction. Congestion prediction is shown on the map as a congestion marker/icon, identified as a possible future incident. PT lines prediction based on average speed and frequency will be represented as colour-coded lines on a geographic map.
	Simulated Scenarios	WP4	The output of simulated scenarios (e.g., % change in flows per road between baseline and an event), should be visible on the transport network map views available. A description of the simulated scenario needs to be easily available for the dashboard user.
	Future scenario	WP4	Selected scenarios of Simulation/Prediction of future timelines/optimization of the network/synchronisation of transit and traffic/ dynamic congestion pricing/ increased bus network, considering that the installed Lisbon transport network is the one proposed at Lisbon Strategic Vision 2030 – 5 future networks.

	Description of the data	Potential Data Source/Stakeholder	Expected Visualisation
	User Recommendations	WP5	Result of optimization techniques based on journey speed across modes to inform the passengers on the best routes. Formatted to be published across different information channels: C-ITS, road PMVs, PT PMVs, dedicated channels, social media, etc.
	Optimization Recommendations	WP5	Result of optimization techniques based on journey speed across modes to synchronise urban and interurban traffic and transit modes, to be discussed among COP stakeholders for cooperative management Depiction of alternative/new routes for traffic flow and transit modes, on top of current state network visualisation, in case of divergence from the route due to incident avoidance, optimization recommendations, etc.
Alerts / Notifications	KPI and LoS alert	WP4/WP5	Notification when certain KPI or LoS are not met. If SNLB or CIM conditions are met, open the corresponding traffic manager menu. *In the following rows, five* examples of relevant situations are listed
	Traffic congestion	Waze, TomTom, Google Maps, Bing Maps - Traffic, INRIX, Moovit (PT modes)	When the average speed for a transport stretch is lower than a given threshold, an alert is shown on the map as a congestion marker/icon.

	Description of the data	Potential Data Source/Stakeholder	Expected Visualisation
	Unplanned events or incidents (others not congestion) happening now	Traffic managers, authorities, PT and Road operators, first responders	A notification appears on the Dashboard stating that an unplanned event or incident is happening now. A general overview of network behaviour, with event delimitation and disruptions detailing, at a dedicated area of the dashboard. Every event is associated with a colour-coded impact assessment, based on some classification (using for example historical data). Hovering over with the mouse on event/incident icons displays relevant information and could lead to a dedicated page with a detailed overview of the situation, where the traffic manager decides whether to require cooperative management or to use automatic optimization to define mitigation strategies; and consults recommended plans, simulated response plans, successful past strategies for solving similar problems etc. A commit button should be available to finalise the decision from the traffic manager. Notifications on incidents can be more intrusive than others (through pop-up banners, and audio alerts). Stakeholder interaction should be facilitated either by COP tools, opening dedicated communication channels or by displaying the contact information of relevant stakeholders (contact person and way of reaching her, telephone numbers, etc.).

	Description of the data	Potential Data Source/Stakeholder	Expected Visualisation
	Planned events or incidents are happening now	Traffic managers, authorities, PT and Road operators, first responders	A general overview of network behaviour, with event delimitation and disruptions detailing, at a dedicated area of the dashboard. Every event is associated with a colour-coded impact assessment, based on some classification (using for example historical data). Hovering over with the mouse on event/incident icons displays relevant information and could lead to a dedicated page with a detailed overview of the situation, a list of involved stakeholders, an area to define a mitigation strategy, recommended plans, considered response plans, successful past strategies for solving similar problems, etc. Stakeholder interaction should be facilitated either by COP tools, opening dedicated communication channels or by displaying the contact information of relevant stakeholders (contact person and way of reaching her, telephone numbers etc.).
Service 2 – traffic management main dashboard	Traffic Manager Operational Centre	Traffic managers, authorities, PT and Road operators, first responders	Dashboard with notifications on decisions required about transport network operation. The notifications should state the needs for an action (e.g., LoS not met), the parties involved (e.g., PT operators), and possibly propose a response plan (e.g., increase of PT capacity). There should be a link to see different graphic maps and there should be a work area for the traffic manager. A commit button should be available to finalise the decision from the traffic manager.

	Description of the data	Potential Data Source/Stakeholder	Expected Visualisation
Cooperative Operational Scenarios	COP Dashboard	COP Stakeholders	The main components of the COP visualisation dashboard are the following: Visualisation of the current and expected status of the network. It will include network performance status (colour-coded KPIs and LoS) at the link or trajectory-level, via measures such as: Traffic flow Realised travel time Estimated travel time Traffic speed Minimum network performance allowed Triggering mechanisms/conditions Response plans/Intervention actions Commit buttons should be available to finalise the decisions with the different involved.
	COP Consensus elicitation	COP Stakeholders	When consensus among stakeholders is required, a dashboard link leads to the consensus-reaching mechanism. Stakeholders state their preferences concerning different objectives through a voting process, where stakeholders provide input to the consensus mechanism by inserting preference data into the corresponding data entry forms. At each stage of the process, the mechanism notifies stakeholders of the degree of consensus and the optimal response plans based on their preferences, via the corresponding messages on the dashboard. Stakeholders must validate the final response plan.

Table 8: Visualisations and interactions preferences for Lisbon

4.2 Rennes

4.2.1 Local context

4.2.1.1 Mobility and policy context

Rennes Métropole is a grouping of 43 municipalities (among which the city of Rennes, the capital of the Brittany region). Métropoles are public authorities enabled by the law of December 16, ,2010[5] and consolidated by the law of January 27, 2014[6]. Métropoles must gather more than 400 000 inhabitants upon their creation. Rennes Métropole population was 444,723 in 2014 (of which 219,370 in the capital city of Rennes). Rennes Métropole is experiencing significant population growth, with a forecast of 100,000 inhabitants additional in 2040.

Rennes Métropole was created in January 2015, replacing the previous *Communauté d'agglomération de Rennes*, which had itself succeeded in 2000 the previous "Rennes district", created in 1970. French Métropoles are in charge of their territory, economic development and territorial planning, waste management and water management, housing policy, culture policy and, finally, mobility, transport, and road infrastructure.

Rennes Métropole, as the Public Transport Authority (PTU)[7], defines the overall transport strategy in its territory through its Urban Transport Plan (PDU[8]) and consequently organises the public transport policy in its 43 municipalities. To promote sustainable mobility throughout the territory, Rennes Métropole is implementing a set of solutions favouring public transport and developing complementarity between the different modes of transport, with a clear choice for innovation and experimentation. Along with a policy of strategic planning, Rennes Metropole developed from 2017 to 2021 the InOut initiative around new mobility to support demonstration and experimentation. As an annual event, input brought together national professional mobility actors ("in") for networking, conferences, showing and facilitating experimentation as well as the public through a dedicated event ("out"), where citizens could learn and experience new mobility solutions.

The figure below shows the main policy orientations and challenges of the PDU.

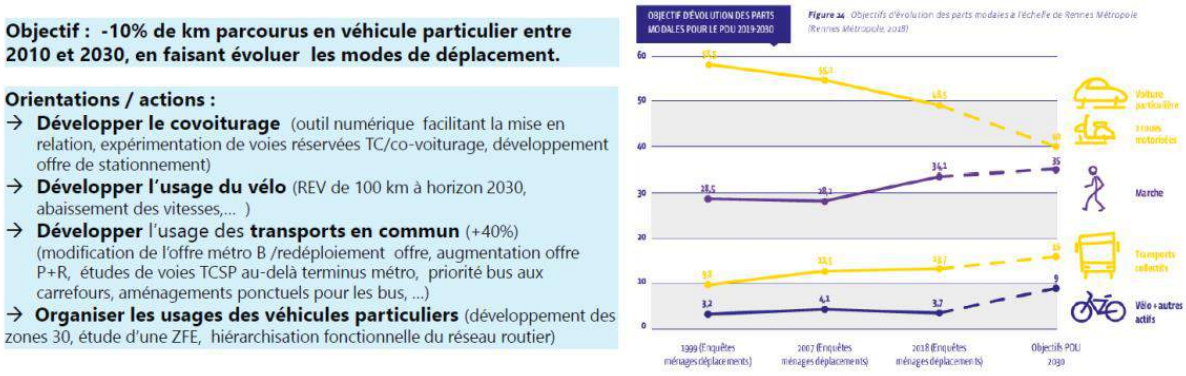

Figure 10: Policy Orientations of Rennes Métropole

[5] LOI n° 2010-1563 du 16 décembre 2010 de réforme des collectivités territoriales

[6] LOI n° 2014-58 du 27 janvier 2014 de modernisation de l'action publique territoriale et d'affirmation des métropoles

[7] Autorité Organisatrice de la Mobilité (AOM) in French, as defined by the 2014 MAPTAM Law (LOI n° 2014-58 du 27 janvier 2014 de modernisation de l'action publique territoriale et d'affirmation des métropoles)

[8] Plan de déplacements urbains 2019-2030 https://metropole.rennes.fr/le-plan-de-deplacements-urbains-pdu-2019-2030

The main policy objective is to reduce by 10% the overall number of trips by private car (in Km) between 2010 and 2030.

Actions include strengthening the use of car-sharing, cycling and public transport and better managing the use of private cars (speed limitation, mitigating air pollution, transport network optimisation).

The case study in Rennes will focus on a specific area which is particularly congested, and which offers the opportunity to test a lot of situations taking place in other areas of the Métropole and even replicating in other cities (replicability). The “route de Lorient” is a penetrating road towards an industrial area but also the way to access (from the West) the football stadium, the Hospital, and the city centre, and it is located near the exhibition centre and the airport. It is also a transit area for travellers and freight as a gate between Brittany and the rest of France.

The TANGENT services should contribute to meeting the above-mentioned challenges, making the most of information on traffic dynamics in real-time (for both traffic managers and users), encouraging car-sharing and the use of soft modes and public transport, planning lanes dedicated to public transport, testing the control of access to the ring road, etc.

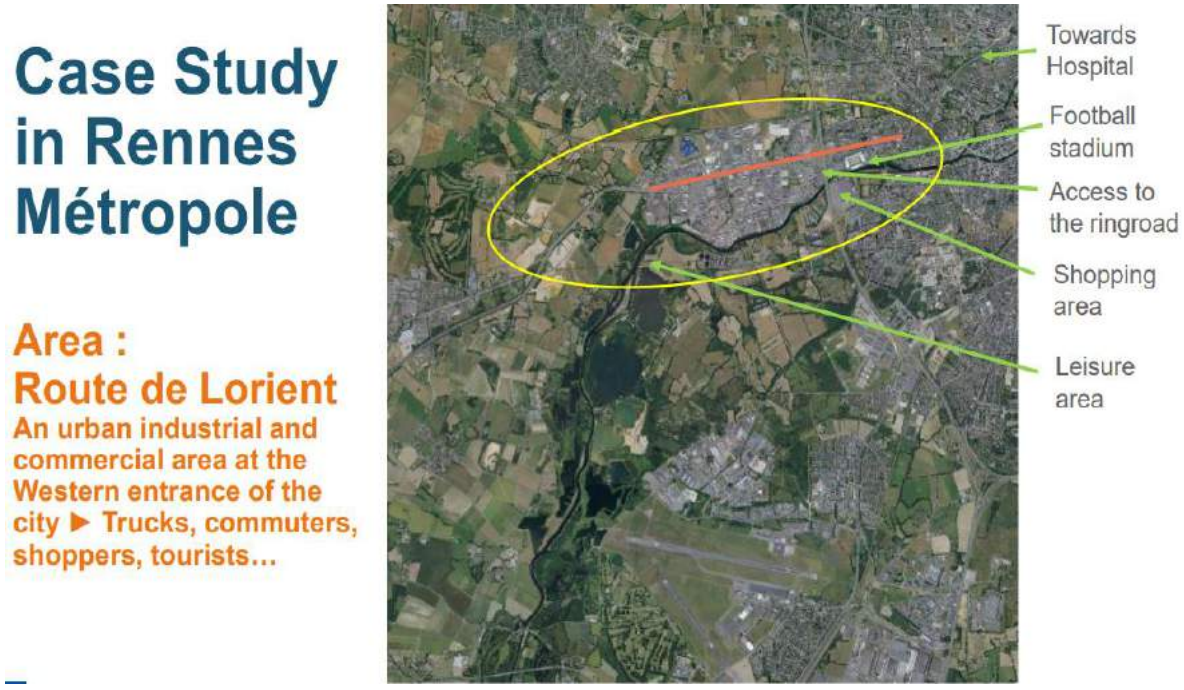

Figure 11: Area of study for TANGENT in Rennes

The main challenge of the route de Lorient area is that traffic is heterogeneous as it connects national roads to the ring roads and highways, resulting in congestion on certain days and hours (in particular Fridays afternoon and specifically in summer with a lot of tourists). Leisure traffic, business traffic and freight transport are mixed.

Consequently, air quality is damaged, and improving it is a major challenge for Rennes Métropole.

4.2.1.2 Introduction of new travel alternatives

The new travel alternative mobility services that Rennes might be interested in, to address the described challenges, care as follows:

- Car includes Car-sharing (observing the great number of people in the cars and the number of cars in car-sharing dedicated car park).
- Cycling, (counting the number of users on the new express cycling lane).
- Tram bus i.e., bus rapid transit (simulation of impact on traffic).

- Cargo-bike last kilometre delivery.
- Car-pooling on dedicated lanes

4.2.2 Characterisation of the transport network in terms of modes, data sources and governance

4.2.2.1 Transport Modes and Services

The Stakeholders for the modes for the city of Rennes are listed below:

Modes	Managing Stakeholder
Metro	KEOLIS Rennes (operating Rennes Metropole "STAR" transport network)
Bus	KEOLIS Rennes (operating Rennes Metropole "STAR" transport network) Breizhgo regional lines
Bike rental and bike sharing	KEOLIS Rennes (operating Rennes Metropole "STAR" transport network)
Carpooling	Citédia operating the CITIZ service for Rennes Métropole;
New carpooling service with private cars and business cars (not available yet but could be an option)	Citédia operating the CITIZ service for Rennes Métropole
Testing Ecov car sharing dedicated lines	Ecov and Keolis Rennes
On-demand	Handistar, taxis
Private car	
Private bicycle and some electric scooters (*trotinettes électriques*)	
Motorbikes	
Infrastructure	DIRO (Direction of Roads) for the ring road and national roads Rennes Metropole for urban network and peripheral roads outside the ring road on its territory County Council for roads outside the territory of Rennes Metropole

Table 9: List of Stakeholders for Rennes

The available traffic modes and services for the city of Rennes are described below:

Public transport:

- Approx. 150 bus lines carry 200000 passengers per day
- metro lines carry 150000 passengers a day and soon much more as the second line is just opening
- 500 disabled persons are transported by on-demand specific services with minibuses

Cycling:

- 650 self-service bicycles are available

- 2000 electric cycles are available on long-term rental

Carpooling:

- 1 regular carpooling line complements the bus services; with 300 departures proposed per day
- This Public service is completed by a park and rides service:
- 5 park and ride parks (soon 8)
- 2100 parking spaces (soon 4100)

Walking: The design of the streets manages to offer more space to pedestrians and more safety in mixed transport. The pedestrian zone in the city is increased with a Limited Traffic Zone tested in the summer of 2022 reducing car access to the centre of the town, with some exceptions for fewer mobile users and their accompanying persons.

Private vehicle is still a large choice for travelling from suburbs to suburbs by is reduced in the centre. Measures like cycle lanes, reduction of the space for cars on streets, park and ride, fast bus lanes etc. are ailing at reducing, even more, the place for cars in the traffic.

The goals for TANGENT tools in Rennes are to support these modal shift strategies, prioritizing public transport and active travel modes where possible.

The travel modes that Rennes would like to prioritise in the implementation of the TANGENT tool are listed below:

- Private cars
- Public transport
- Car-sharing
- Cycling
- Walking

4.2.2.2 Transport Infrastructure

The relevant infrastructure and tools for Traffic management in Rennes are

- Smart traffic lights with predefined regulation through the control centre ("PC Arthur").
- Rennes Metropole sensors (counting numbers of cars, speed, identifying congestion and adapting traffic light programmes)
- 300 sensors for monitoring traffic
- 23 sensors SIDERO on Rennes Métropole road network (they are sensors embedded into the road surface, able to count the number of vehicles, which type of vehicle according to the number of wheel axles, road occupation rate, speed of vehicles, the distance between vehicles)
- 6 sensors for counting pedestrians and cyclists
- 1500 traffic lights are managed for priority settings
- Variable message signs: not on the chosen area but nearby on the ring road and upstream.
- Fixed air quality sensors could be installed with Air Breizh and be connected to the Rennes Métropole LoRa network to analyse CO2, NO2, pm 2.5 et 10.

4.2.2.3 Overview of data sources

Further information on data sources can be found in the deliverable D2.1 will develop this further.

4.2.2.4 Characterisation of governance

The governance process in Rennes is based on 3 pillars: ad hoc cooperation for key events; crisis management and regular committees on joint key issues.

1. **Cooperation for planned events**

- Football matches: Impact on the ring road and the parking on the area of the stadium, impact on the organisation of public transport and security organisation.
- SPACE (SPACE 2022 - Salon international de l'élevage) – 3 days every year in September (70,000 to 100,000 visitors each year)
- Music festivals: Impact in the evening on parking, traffic, and security. The main one is the "Transmusicales" – a music festival every year in December (up to 60000 visitors each year). It is noted that KEOLIS Rennes has a person dedicated to managing these events.

For these three main events and types of events, the key stakeholders meet in advance to plan the management processes and the measures to be implemented. These meetings involve Rennes Metropole, the DIRO (Direction Regionale des Routes de l'Ouest) representative organisation of the national road management body, managing the West France roads, and responsible for the ring road management; the police and the "Prefecture" representing the national government; KEOLIS Rennes (PT operator).

2. **The cooperation process** for the strategic and operational level existing in the infrastructure system for Rennes is described below:

Operational:
The "Thursday Meetings": every Thursday the key stakeholders meet for working jointly on the operational management of the traffic in the metropolis and updates on main programmed equipment, works etc. impacting traffic management in the short and medium term. These meetings involve DIRO, Keolis Rennes; in Rennes Metropolis the following services: traffic management, Works planning service, Waste management service, and communication service to inform citizens about works. When needed other actors are involved (real estate operators, etc).

Strategic:

- The local mobility plan management committee: this committee monitors the implementation of the local Mobility Plan (SUMP), it is called the COPIL – PDU and involves Rennes Metropole, representative of the national government (Prefecture), the Brittany Region, the Pays de Rennes (territorial organisation), the Department Council of Ille-et-Vilaine (territorial organisation gathering several territories around Rennes.

The local traffic management master plan management committee involves Physical meetings that are also organised to analyse traffic disturbance, interruptions, etc.

Events/crises in the prefecture + DDTM (DIRO, Rennes Métropole CD) determine a pre-established management plan.

One of the strengths of Rennes: Keolis Rennes has a person dedicated to events (e.g., music festivals, etc.).

COPIL PDU (Rennes Metropole, State, Region, Pays de Rennes, CD35) (steering committee of the local mobility plan)

SDAGT (Rennes Metropole, State, CD35, Region) (Agglomeration Traffic Management Master Plan)

- Rennes Metropole, the representative of the national government (Prefecture), the Brittany Region, and the Department Council of Ille-et-Vilaine. It works on the overall traffic management strategy, coordination of the territorial organisations, necessary upgrading of the equipment etc.

3. Crisis management:

- For other events and crises, two stakeholders work together: a specific body exists which gathers the main stakeholders: To contribute to the balanced development of the territories in

Ille-et-Vilaine, the DDTM, inter-ministries technical service, placed under the Prefect, implements public agricultural, maritime, environmental, town planning, housing, risk, and transport. It gathers in this specific case of transport and traffic emergencies; the Prefecture, the DIRO and Rennes Metropolis. It determines pre-established management plans.

The main challenge resides in the involvement of external actors, beyond those above described; especially the private transport actors and operators such as taxis, UBER, and vehicle renting agencies. Specific attention is placed on the emerging need for cooperation with operators such as WAZE, which activities and services can be antagonists to the traffic management strategy and event management plans developed and implemented by the territorial actors. The same goes for GOOGLE, with whom Rennes Metropole has already contacts. We estimate that such discussions are necessary for the framework of TANGENT.

Another challenge exists for cooperation in the logistics sector: Rennes Metropolis launched a “Logistic Charter” for gathering the key stakeholders and setting priorities for the logistics in the city and suburbs. An organization called Bretagne Supply Chain (BSC), gathering private goods transport operators and logistics platforms, works with Rennes Metropolis on this strategy. In the framework of TANGENT, BSC will be involved as an external actor in discussing how the best provide information to those actors on traffic conditions.

Keolis Rennes is the public transport operator for Rennes Métropole and also a partner of project TANGENT

DIRO: open to cooperation, especially as it is a key partner of all the governance processes described above.

Regional authority/Breizhgo: to be initiated, not very cooperative so far (need to discuss at least on traffic management shared objectives)

Users’ acceptance may depend on the wide take-up of the services and information tools provided by TANGENT. In this respect, it might also depend on depending on discussion with Waze and Google.

With Taxis, difficult to discuss in general so it will depend on how we want to involve them in the TANGENT project (we plan to involve them as external actors for updates on the services)

As we focus our case study on the “Porte de Lorient” where traffic is heavily impacted by the main planned events we listed, and where strategic equipment is under construction (cycling, bus lanes etc) we expect increased cooperation between traffic and infrastructure managers (Rennes Metropolis, DIRO) & transport operators (KEOLIS, Breizhgo). We expect the reinforcement of the operational cooperation and efficiency of the cooperation processes through the joint work on TANGENT. For achieving this, the TANGENT calendar will have to be articulated with the calendar of key decisions to be made (in particular the revision of the Traffic Management Centre specifications and its replacement).

4.2.3 Stakeholder mapping

This table provides an overview of the local stakeholders and their role in each of the services and functionalities.

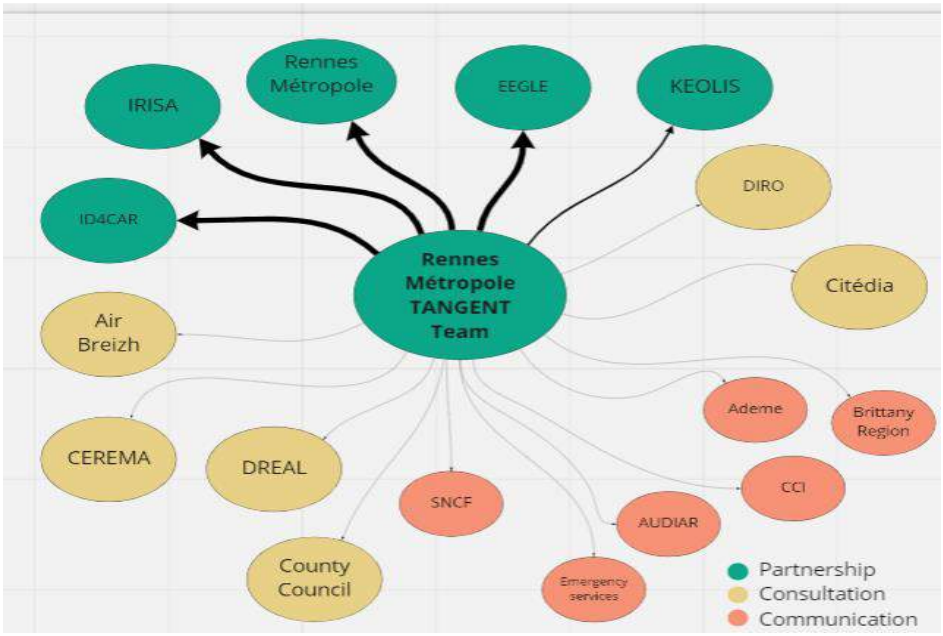

Figure 12: Rennes Stakeholder mapping

Stakeholder	Nature	Engagement
ID4CAR	Cluster of companies and R&D laboratories in West France	partner
KEOLIS	PT operator in Rennes	partner
Rennes Metropole	Metropolitan authority	partner
IRISA	R&D laboratory of the Rennes University	Partner of Rennes Metropole for data management project
EEGLE	SME	Partner (TP of ID4CAR)
DIRO	National road manager	Consultation and data provision
CITEDIA	Urban mobility manager (private)	Consultation and data provision
Air Breizh	Air quality monitoring	Consultation (data provision on air quality)
CEREMA	Research centre (national) on transport and infrastructure	Consultation
DREAL	Regional agency for the environment, land use planning and housing (depending on national government)	Consultation
County Council	County public authority, road manager	Consultation
SNCF	Trains national manager	Consultation
Emergency services	Firemen Police etc	Consultation
AUDIAR	Agency for land use planning studies (Regional + National)	Consultation

Stakeholder	Nature	Engagement
ADEME	National Environment Agency	Consultation
Brittany Regional authority	Regional authority (manages regional trains)	Consultation
Chamber of Commerce	Private sector representative	Consultation

Table 10: Description of all the Stakeholders for Rennes

TANGENT Sub-service	TANGENT Functionality	Stakeholder type	Role	Name of the local stakeholder
TANGENT Service 1: Enhanced information service for multimodal transport management				
Real-time information	Visualise the current status of the network	Infrastructure provider - Traffic managers and PT operators	To monitor the transport network. To monitor mode-specific operation for bus	Rennes Métropole Control Center = (PC Arthur) KEOLIS Rennes Brittany Region (BREIZHGO coaches) DIRO
Predictive Information	Visualise the future status of the network	Infrastructure provider - Traffic managers and PT operators	Visualize and assess the new interface and its effects Encourage users to choose their modes as per the situation,	Rennes Métropole Control Center = (PC Arthur) KEOLIS Rennes Brittany Region (BREIZHGO coaches) DIRO

TANGENT Service 2: Real-time Traffic Management Services				
Smart Network Load Balance:	Informing the transport passengers	Infrastructure provider - Traffic managers and PT operators	To monitor the transport network across all modes. utilise social media and journey planning apps of incidents	Rennes Métropole Control Center = (PC Arthur) KEOLIS Rennes Brittany Region (BREIZHGO coaches) DIRO
Cooperative Incident Management:	Synchronisation of transit and traffic	PT operator Local Authorities Urban services operator	Monitor and manage the transport network across modes, communicate info between stakeholders	Rennes Métropole Control Center = (PC Arthur) KEOLIS Rennes Brittany Region (BREIZHGO coaches) DIRO
TANGENT Service 3: Transport network optimization for Transport Authorities				
Simulation of scenarios suggested by the decision maker		Public Transport Operator, Local Authorities Urban services operator	user of service 3, definition of scenarios, data provider	Rennes Métropole Control Center = (PC Arthur) KEOLIS Rennes DIRO (BREIZHGO coaches)
Generation of Response Plans		Public Transport Operator, Local Authorities. Urban services operator	user of service 3, definition of response plans, cooperation with other stakeholders to define a response strategy, implementing a response plan	Rennes Métropole Control Center = (PC Arthur) KEOLIS Rennes DIRO (BREIZH GO coaches)

Table 11: Stakeholder mapping Rennes

4.2.4 Traffic Management Strategies

The strategies involved in traffic management in the city are listed below:

- Travel behaviour management (through information provided to the user)

- Prioritising public transport
- Synchronisation of traffic and public transport
- Car sharing on dedicated lanes

4.2.5 Transport Modelling

The city of Rennes has developed and worked with a PTV Visum model since 2007 for their study of macroscopic travel demand.

The transport model used by Rennes using Visum has been calibrated in 2009 (based on the 2007 EMD survey), 2015 and 2020-2021 (based on the 2018 EMD survey). The last calibration includes bike and car-sharing modes in addition to the conventional modes. (EMD = Enquête Ménages Déplacements (survey to the population about mobility). An Origin-Destination survey and a mobility survey are planned for March 2023. Data will be integrated into the model during the last quarter of 2023.

The transport model includes the following modes:

- Public transport: Public transport of the city includes the transport modes of Bus and metro from the Star network covering Rennes Métropole and operated by Keolis Rennes. Also includes Coaches from the Breizhgo network managed by the Regional Council of Brittany and Trains.
- Bikes
- Cars (VPC Voiture Particulière Conducteur/driver and VPP Voiture particulière Passager/passenger)
- Freight transport and business trips.

4.2.5.1 Network supply information.

The network supply is based on the information from different sources as follows:

- Socio-demographic data (population, employment, attraction zones such as areas of employment, area of universities)
- Floating Car Data on Rennes Métropole area
- On-site counting of vehicles
- Public transport lines, stops and schedules (buses, coaches, trains) – GTFS data for trains.
- Bicycle lanes
- Traffic/Transit control plans

The area covered by the transport network covers Rennes Métropole (yellow), The rest of the Ille-et-Vilaine County (violet), Part of the Côtes d'Armor county (green), and Part of the Morbihan County (grey). The jurisdictions are shown below in Figure 13.

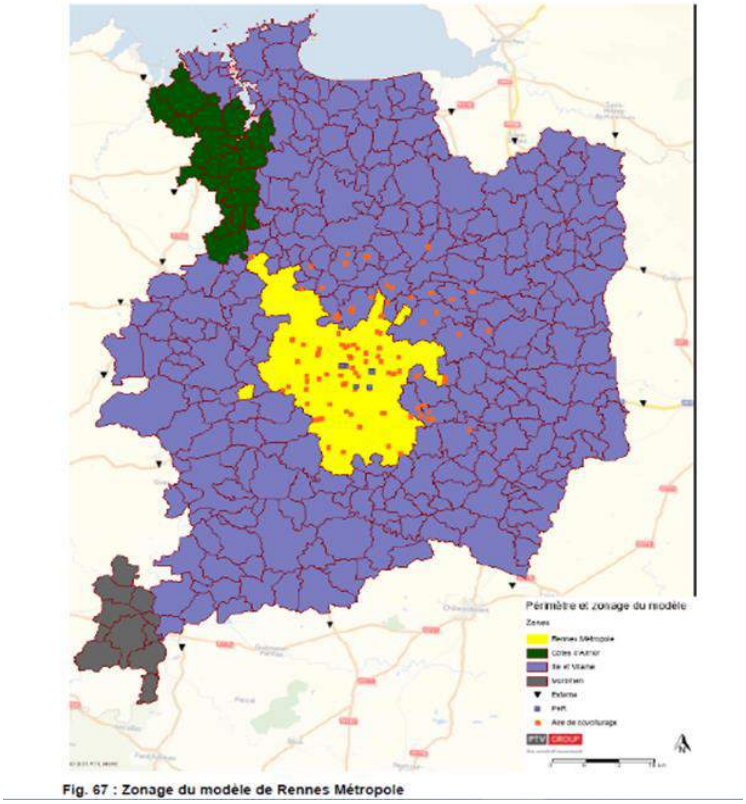

Figure 13: Map showing the different sections of the transport network of Rennes.

The zoning of the model consists of 1,524 zones, distributed as follows:

- Areas within the perimeter 1,385
- Rennes Métropole1,058
- Ille et Vilaine 290
- Côtes d'Armor 26
- Morbihan 11
- Areas outside the perimeter 15
- Intermodal zones 124
- P+R 8
- Carpooling areas 114

The type of traffic measurements that have been used to calibrate and validate the traffic model includes the peak hours identification, and identification of the user categories like employed with or without a private car, students, etc. The peak hours are as followed:

- Morning period peak: 07:00-09:00
- Evening period peak: 16:00-19:00
- Morning hour peak: 08:00-09:00
- Evening hour peak: 17:00-18:00

Also, the mobility purposes and the traffic infrastructures were put added to the model. Samples of travel time based on FCD and google traffic were used to check the travel time results given by the model on predefined routes. Public transport networks with their service frequencies, school buses, bicycle lanes and car park areas were also modelled in Visum. Intermodal parking load and carpooling based on car parks were also put introduced into the model. Speed modelling for bicycles was also considered. Car park areas with intermodal parking loads (parking at the beginning of a metro line) and carpooling services are also considered for the calibration process.

An update of the above-described model is due in March 2023 and integration of data into the model would begin from the last quarter of 2023.

4.2.6 Impact canvas per TANGENT service

TANGENT Services	Objectives	Case Study Description and requirements	Target users and benefits	Expected Impact	Challenges
(1) Enhanced information service for multimodal transport management – Dashboard & API	To know about the real-time traffic situation along different modes. Better usage of traffic modes and control of the same.	Individual transport (cars, motorbikes, bikes, pedestrians) Public Transport, Car sharing, Taxi services	Rennes Metropole, KEOLIS	Better visualization of traffic along different elements Monitor the flow of traffic and passengers Detection of breakdowns along traffic modes	Data storage capacity Synchronisation among different actors Availability of Data
(2) Real-time Traffic Management Services	To know about traffic situations in real-time and know about break downs and over-capacities in the network To be more responsive through dynamic traffic management for the 2 network managers To allow/encourage users to be able to choose their mode according to the state of the transport network	Individual transport (cars, motorbikes, bikes, pedestrians) Public Transport, Taxi Emergency services freight	Rennes Metropole, KEOLIS SDIS, French Police Emergency services	Decongesting traffic flows suggesting different directions Real-time information is available to users for their easy choice Encouraging users to take different routes	Data guarantee, Results of the tool based on the Data Coordinate mobility policies Control of traffic reports

TANGENT Services	Objectives	Case Study Description and requirements	Target users and benefits	Expected Impact	Challenges
(3) Transport network optimization for Transport Authorities	Evaluate different traffic regulation scenarios, Fluidity in mobility modes	Individual transport (cars, motorbikes, bikes, pedestrians) Carpooling Public transport	All urban services Rennes Metropole	Decision support Adaptation of transport strategies in real-time Better coordination among operators Pollution control	Synchronising the new behavioural changes into the system for optimising the network.

Table 12: Impact canvas per TANGENT service

4.2.7 Scope and Scenarios definition per TANGENT Services

TANGENT Service 1: Enhanced information service for multimodal transport management							
Functionality		**Objectives**	**Scope: Virtual or Real (where?)**	**Baseline Scenario**	**Planned Event(s)**	**Unplanned Event(s)**	**Future Scenario(s)**
Real-time information	Visualise the current status of the network	- To promote data sharing - Provide traffic dynamics in real time - Identify delays To have a view of the transport network for all modes (present on the test site areas). Current network status and real time conditions, with mapped user interface. Disruption and con gestion hot spot and evolution.	Gather and process data among different stakeholders Real (onsite)	The current status of the network is displayed on the traffic management centre monitoring tools. Commuters travel; weekend and holidays travels, normal conditions	Sport events; music festivals; departure/return from long weekends and holidays, large fairs, demonstrations, and strikes (in public transport)	Unplanned works, accidents, and incidents diverted traffic. Climate change related hazard as floods	Impact of the new equipment (bus lanes); of lane allocation on the ring road

Predictive Information	Visualise the future status of the network	Forecast the network to identify congestion and bottlenecks: centralised view of the transport network. Future network status and predicted status of the network. Impact of disruptions and congestion hotspot flagged. (In the site area)	Real	Commuters travel; weekend and holidays travels, normal conditions	Football matches, Exhibition centre events, SPACE, Transmusicales, demonstrations, and strikes (in public transport)	unplanned road works: accidents, incidents and diverted traffic	Impact of major works and strategic changes in the network

Table 13: Scope and Scenarios definition for Service 1 for Rennes.

TANGENT Service 2: Real-time Traffic Management Services							
Functionality		**Objectives**	**Scope: Virtual or Real (where?)**	**Baseline Scenario**	**Planned Event(s)**	**Unplanned Event(s)**	**Future Scenario(s)**
Smart Network Load Balance:	Informing the transport passengers	To inform the users on disruptions, congestion, and incidents as well as predictions of planned event to allow them to use other alternative routes or shift to PT. Information should be on disruptions, network status and options. It should also be usable for response plans. Info available on multi channels (public and private). Information should include specific mode information (events and network status)	Real with applications (STAR for PT, Rennes Circul' for Rennes Network infrastructure, Bison futé for National roads), and potentially other partners (Waze etc)	Information through existing channels, Public (Star l'appli, Rennes Circul, Bison Fûté) Private (Waze and Google). For commuters and WE/holidays travel under normal conditions.	Football matches, Exhibition centre events, SPACE, Transmusicales, demonstrations, and strikes (in public transport)	Disaster management Climate change related hazard as floods; unplanned road works; accidents, incidents and diverted traffic	

		and response plans (alternatives?)					
Cooperative Incident Management:	Synchronisation of transit and traffic	Identify coordinated actions to be taken by traffic managers and transport operators in cas of planned events such as football matches or unplanned events	Virtual	No traffic and transit synchronisation (except for increase of PT service in case of football matches as already defined in the contract between Rennes Métropole and Keolis Rennes)	Huge traffic during events such as Football matches with impact in the whole Southwest of Rennes Métropole	Emergency situations (fire, terrorism, etc) Climate change related hazard as floods; unplanned road works; accidents, incidents and diverted traffic	Simulation of mobility scenarios such as stronger PT offer and diversion of private traffic

Table 14: Scope and Scenarios definition for Service 2 for Rennes.

TANGENT Service 3: Transport network optimization for Transport Authorities							
Functionality		**Objectives**	**Scope: Virtual or Real (where?)**	**Baseline Scenario**	**Planned Event(s)**	**Unplanned Event(s)**	**Future Scenario(s)**
Common operational picture generation tool		To share mobility strategies from the different traffic managers and transport operators and to achieve a visual common strategy.	Virtual	Each traffic manager and transport operator has their own central traffic management centre and share partial information	Planned events such as football matches	Same as above	Common operational picture generation tool
Response plan generation support Tool		Having new insights to produce smart response plans	Virtual	Current joint response plans between key stakeholders	Planned event such as football matches	Same as above in particular road closure in case of hazardous situations	Decide about new response plans to be applied by each stakeholder. Simulation of pre-defined scenarios
Simulation of scenarios suggested by the decision maker	What-if scenario 1: Priority is given to vehicles with 2-3 passengers (car-pooling) by lanes management	Impact on the traffic flow and congestion; impact on use of car pooling	Virtual (depends on the date of the decision to allocate lanes on the ring road)	No current lane allocation.	Traffic during events: Football matches, Exhibition centre events, SPACE, Transmusical Daily commuter traffic.	Incidents leading to congestion, PT strikes, accidents,	Simulation of impact on the flows, on traffic density, parking.

Table 15: Scope and Scenarios definition for Service 3 for Rennes

4.2.8 Visualisation and Interaction

	Description of the data	Potential Data Source / Stakeholder	Expected Visualisation
Data from Existing Data-sources	Traffic flow visualisation	Rennes Metropole DIRO	Traffic flows appear on a map with 'hot spots" visualisation for better route management, for both private vehicles, emergencies, and public transport (update to 5 minutes or real-time).
	Rapid transit BUS traffic management	KEOLIS bus operator, DIRO	Congestion of the Reserved Bus Lanes, visualisation of traffic flows and prediction of congestion evolution, Live position of buses and delays planned. Less than 5 minutes updates
Predictive Information	Traffic flow predictions on strategic roads (ring roads)	DIRO	Visualisation of traffic flows on the ringroad portion with impact on the Porte de Lorient (tests site) traffic. A timeline should be visible to show the available period with predictions and it should be clear the viewed data is not live but a prediction.
	Traffic flow predictions on main arterial roads	Rennes Métropole	Visualisation of the traffic flows predictions on the main roads impacting the traffic on the Porte de Lorient site. A timeline should be visible to show the available period with predictions and it should be clear the viewed data is not live but a prediction.
Alerts / Notifications	Bus reserved lanes are congested	Bus operator KEOLIS	A notification appears on the Dashboard stating that the Bus lanes are congested and an indication of the delays
	Traffic congestion (from radars/traffic counters)	RM and DIRODIRO	Alert shown on map as a congestion marker / icon. Happens when certain KPI or LoS are not met (the average speed for a stretch is lower than given threshold or vehicles number is higher than a given threshold.)
	Weather conditions deterioration	All PTPT and road operators	Alert in case of sudden deterioration of weather conditions impacting road safety and traffic; (data TBC – partnership with Meteo France), to be shown on the maps as a dedicated marker/icon (illustrating the problem: storm, wind, etc). Happens when certain KPI or LoS are not met (the average speed for a stretch is lower than the threshold speed or the number of vehicles is higher than a given threshold.

	Description of the data	Potential Data Source / Stakeholder	Expected Visualisation
	Bus reserved lanes are congested	Bus operator KEOLIS	Notification appearing on the Dashboard stating that the Bus lanes are congested with an indication of the delays
	Alert for incidents and accidents on roads	DIRO - RM	Alert in case of an accident and/or incident impacting traffic, including demonstrations etc.
Cooperative Operational Scenarios	During a large event, it is necessary to increase public transport capacity and manage access to ring road and parking spaces	RM, KEOLIS, DIRO (Prefecture), Municipal Police	If CIM service, at the dashboard, there should be a notification stating the need for cooperation between the different parties If a SNLB service, should be triggered by predictions and at the dashboard an alert indicating reaching trigger level should appear
	Unplanned events: emergency and/or crisis plans	RM, KEOLIS, DIRO (Prefecture), Municipal Police	Plans to be prepared in advance and triggered by a change in the “normal” situation on the site
Other inputs for decision making	Road works are impacting the road and bus network	RM and KEOLIS – DIRO and Breizhgo coaches	In the dashboard, there should be a notification stating the need for a decision from operators to jointly plan alternatives
	Air quality alert	DIRO + RM and KEOLIS Air Breizh/prefecture	In the dashboard, there could be a triggering alert when the air quality is bad as DIRO (and Rennes Metropole) apply traffic (speed) restrictions on the ring road mainly; PT offer can be increased to compensate (FEZ to be developed in Rennes)

Table 16:Visualisation and Interaction preferences for Rennes

4.3 Manchester

4.3.1 Local context

4.3.1.1 Mobility and policy context

The key priorities for the city of Manchester are promoting the use of sustainable transport modes, reducing traffic congestion, having a fully integrated transport network and reduction in carbon footprint.

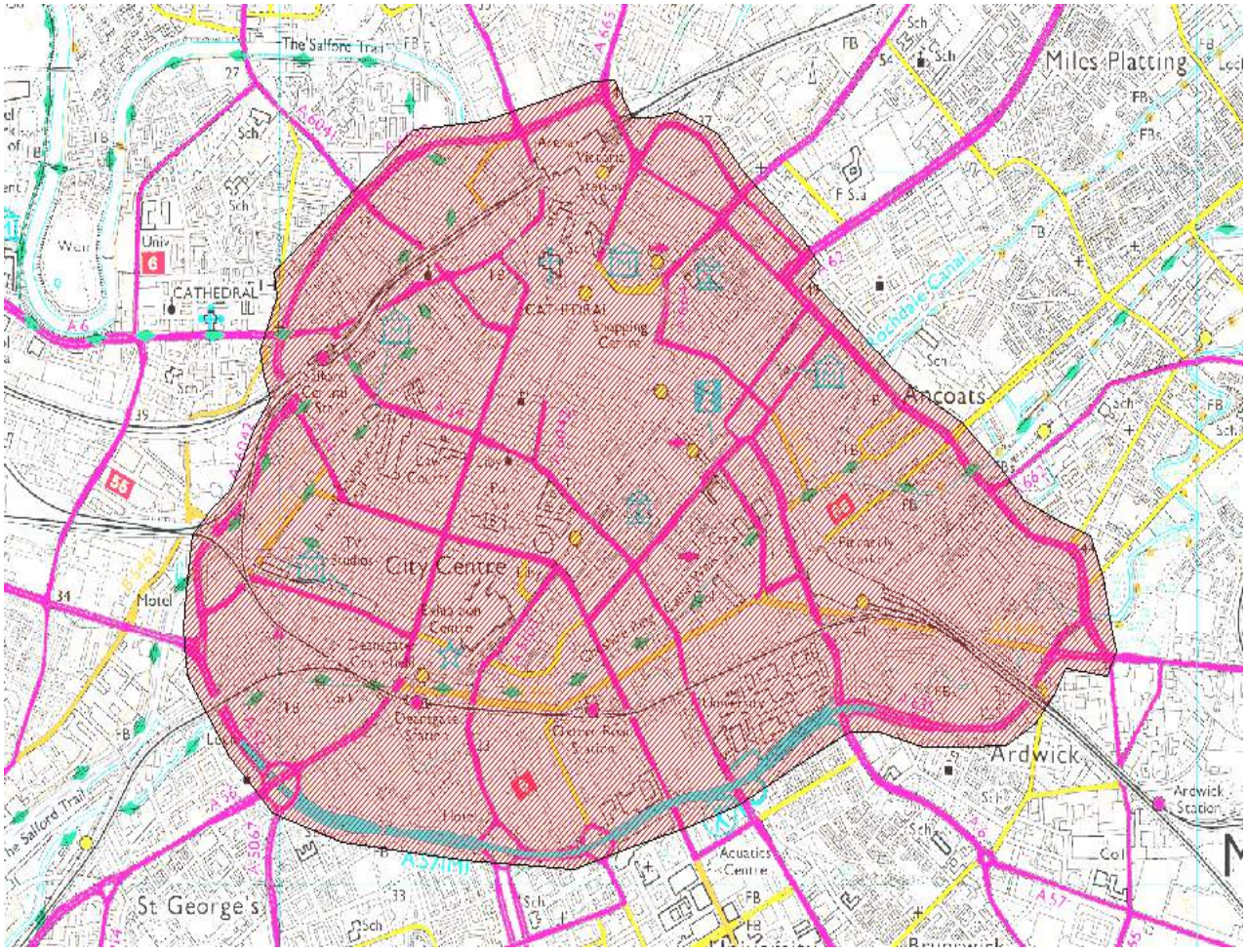

Figure 14: Area within and including Manchester Inner Ring Road

The city plans to test the services from this project within the inner ring road. The city will also look to include travel corridors to/from Old Trafford and the Etihad football stadiums.

The challenges faced by the city of Manchester that would be addressed through this project are mainly managing congestion, integrating the different modes of transport like bus, tram, train, and active travel, and encouraging a modal shift to sustainable modes. One of the other main challenges for the city is to integrate traffic management systems and data to ensure that the transport network could be overall managed. Also, a concern for the city is understanding how future mobility can shape the transport systems.

4.3.1.2 Introduction of new travel alternatives

Mobility services, that would interest Manchester to address the above-mentioned challenges, are to include the first and last mile services alongside the existing public transport network and the inclusion of

Demand Responsive Transport (DRT). Other alternatives for Manchester would include the CAV shuttles, encouraging parking outside of the regional centres and at rail and Metrolink stations.

4.3.2 Characterisation of the transport network in terms of modes, data sources and governance

4.3.2.1 Transport Modes and Services

Like most major city regions, Greater Manchester is host to a variety of modes of transport. These include:

- **Bus**: The network of approx. 719 services are provided on both a commercial and subsidised basis by over 35 individual operators). This is to change under the Bus Reform plans (2023 - 2025).
- **Tram**: TfGM owns the Metrolink tram service, which is the largest light-rail network in the UK (99 stops over 62+ miles, carrying more than 40 million passengers a year). The service is operated by KeolisAmey Metrolink.
- **Rail**: Greater Manchester has 97 rail stations, offering more than 70 direct connections to major cities and towns across the country. The services and stations are privately owned and operated.
- **Walking:** Significant investment is taking place in supporting walking and cycling infrastructure across Greater Manchester. At 1,800 miles in length, the network will be the country's largest walking and cycling network, taking 10 years to deliver at a total cost of £1.5 billion. When complete, it will connect every neighbourhood of Greater Manchester
- **Cycling**: As above, substantial investment is supporting the rollout of vast amounts of dedicated cycling infrastructure across the region. Cycle hire - Transport for Greater Manchester, working in partnership with Manchester City Council, Salford City Council and Trafford Council, has launched Greater Manchester's first publicly operated, self-service, 24/7 cycle hire scheme. Includes up to 1,500 bikes - including e-bikes (once completed).
- **E-scooter**: Transport for Greater Manchester is working with Rochdale Borough Council, Salford City Council, and e-scooter operator Lime as part of a wider Department for Transport trial to see how e-scooter rental schemes can be successfully operated in the UK.
- **Private hire:** Local authorities grant and manage private hire licences across Greater Manchester. Uber has operated in Manchester since 2014.
- **Private vehicle**: Currently the most common choice for journeys in GM.

The Stakeholders for the concerned modes for the city of Manchester are listed below:

- TfGM:
    - Work closely with bus, tram, and train operators to help improve the full journey experience.
    - Own Metrolink – the UK's largest light rail network – and plan for its future, including the new Trafford Park line.
    - Promote and invest in walking and cycling as safe, healthy, and sustainable ways to travel.
    - Pay for bus services at times and in areas where no commercial bus services are provided.
    - Keep traffic flowing on some of Greater Manchester's busiest roads by managing a 360-mile 'Key Route Network'.
    - Own Greater Manchester's bus stations, stops and shelters and invest in new, modern transport interchanges.
    - Subsidise more affordable fares to help older people, children and disabled people get around.
    - Develop easier, smarter ways to travel and plan your journey by using data and technology.
    - Play a leading role in coordinating Greater Manchester's plans to reduce transport-related air pollution.
- Greater Manchester districts: Bolton, Bury, Manchester, Oldham, Rochdale, Salford, Stockport, Tameside, Trafford, Wigan. The districts remain the Highway Authority across Greater Manchester, and so are ultimately responsible for highway maintenance, private hire licensing and roadworks approval.

- Bus operators: Stagecoach, Go Northwest, Arriva, and Diamond are the largest operators in GM (currently - Bus Reform process delivered 2023 to 2025).
- Metrolink: Owned by TfGM, operated by KeolisAmey Metrolink.
- E Scooter: Lime (trails in Salford and Rochdale).
- National Highways: Own and manage the Strategic Route Network (SRN).
- Network Rail: Owner and infrastructure manager of the railway network. Own and manages Manchester Piccadilly Railway Station.
- Train operators: Northern, Arriva, CrossCountry, TransPennine Express, Avanti West Coast (and others). Own and manage most stations across Greater Manchester.

As part of TfGM's 2040 Transport Strategy, the ambition is to achieve the 'Right Mix' transport vision. This aims to reduce car's share of trips to no more than 50%, with the remaining 50% made by public transport (Bus, Metrolink/Tram, and Rail), walking and cycling. We hope to align the implementation of the TANGENT tool with this ambition, prioritising public transport and active travel modes where possible.

4.3.2.2 Transport Infrastructure

TfGM utilises a variety of technologies and tools to manage and optimise the transport network across Greater Manchester. These include:

- **Bluetooth Passive Journey Time Sensors**: There are approx. 500 sensors, installed at traffic signals across key corridors and strategic routes. Capturing anonymised MAC addresses of cars/devices, these are used to understand point-to-point journey times daily.
- **Automatic Traffic Counters (ATC):** There are approx. 150 inductive loop count sites across the highway network, capturing vehicle flow, speed, and classification at key locations.
- **Automatic Cycle Counters (ACC):** There are approx. 90 piezo-electric cycle count sites across Greater Manchester (some of which are 'off-road', e.g., canal towpaths, greenways etc.). These capture cycle volumes at strategic locations.
- **Video analytic sensors:** TfGM makes use of data from over 200 video analytic sensors, using artificial intelligence to provide count/class/speed data from the highway and wider public realm, with a particular focus on capturing active travel modes (cycling and walking).
- **Drakewell C2:** TfGM makes use of the cloud-hosted Drakewell system, C2. Data from the above technologies (ATC, ACC) is stored here, enabling easy sharing of the data through an API.
- **Variable Message Signs (VMS):** TfGM has a network of over 60 VMS at key sites/corridors across the region providing incident/event information, roadworks, and wider strategic communications.
- **Urban Traffic Control (UTC):** TfGM monitor, manage and optimise traffic signals using the UTC-UX system (Yunex). 'Traditional' adaptive technologies are regularly adopted, with over 1000 sets of signals operating SCOOT, and 250+ operating MOVA.
- **Common Database (UTMC System):** TfGM utilises a UTMC common database system, bringing together multiple data sources, and empowering control centre operators/users to use information from across the network to make informed decisions/interventions (e.g., traffic signal strategies).
- **Smart Junctions** - TfGM continues to trial the operation of AI-controlled traffic signals, working with Vivacity on a machine-learning-based agent that makes use of the video analytic sensors mentioned above. Technology to facilitate this has been installed at approx. 20 junctions around the regional centre.
- **CCTV**: The TfGM Control Centre has access to over 2000 CCTV cameras (monitoring only) across the Highway Network, transport stations/interchanges and Metrolink stops.

- **Waze**: TfGM is part of the Waze Connected Citizens program. Waze exchanges publicly available journey time data in addition to incident and road closure reports, enabling TfGM to respond more immediately to accidents and congestion on their roads. In turn, Waze aggregates our partners' data on the Waze platform, resulting in thorough overviews of current road conditions.

4.3.2.3 Overview of data sources

Further information on data sources can be found in the deliverable D2.1 will develop this further

4.3.2.4 Characterisation of governance

TfGM Control Centre cooperates with mobility actors across the city to manage the network, particularly in times of disruption.

- **Bus Operators** – We communicate with bus operators in times of disruption, such as a road closure, to determine their diversion route and coordinate diversion routes with other operators. Bus operators will also report issues to the TfGM Control Centre as their drivers come across them, e.g., temporary signals not working. Communication between operators and TfGM is primarily by phone and email, however, Stagecoach representatives are co-located within the TfGM Control Centre.
- **Keolis Amey Metrolink (KAM)** – TfGM Control Centre acts as the escalation route from KAM to TfGM for any disruptions to service. TfGM Control Centre then escalates this information through TfGM, to senior managers if strategic decisions are required.
- **National Highways** – TfGM Control Centre communicates regularly with National Highways who manage the motorway network. Disruption on the motorway network can quickly extend to the Key Route Network, and vice versa. Therefore, we must communicate disruption between us to mitigate impacts. Communication between National Highways and TfGM Control Centre is primarily by phone, but also via disruption notifications by email.
- **Network Rail** – Disruption on the rail network is communicated to TfGM Control Centre by email disruption notifications. If more information is required regarding disruption, TfGM Control Centre can contact the Network Rail Route Operating Centre via phone.
- **Emergency Services** – Primarily, TfGM Control Centre communicates with Greater Manchester Police (GMP) the most, particularly regarding road closures that the police have implemented which may disrupt service, crime on the network and during large events. Communication with GMP is either by phone or email, but recently a GMP officer is now co-located in the Control Centre. For large events, a representative from TfGM Control Centre may also be present in GMP's Force Command Module.
- Northwest Ambulance Service and Greater Manchester Fire and Rescue Service are contactable via phone if required.
- **TfGM (Internal)** – TfGM Control Centre liaises with multiple departments across TfGM, including senior management (escalation), Urban Traffic Control (traffic signal changes), modal leads on calls, traffic, and corridor managers (roadworks), bus stations (disruption to services), customer team (customer messaging) and many more. Communication between the Control Centre and TfGM departments is via phone, email, or instant message.

The challenges faced by the city in terms of cooperation among the mobility actors, especially in the case of planned and unplanned events, are described below:

A key pain point is the amount of duplication of information and double keying. For example, if there is disruption on a route in the City Centre, we have to phone: multiple operators, TfGM Bus Station Colleagues, UTC and KAM. Concurrently, this same information is recorded in an incident record, pushed out to customers via social channels and sent out as a Service Disruption Notification. As such, this can

result in the same information being exchanged written and verbally over 7/8 times for a straightforward incident.

Another issue is operator awareness of others' actions. For example, while TfGM Control Centre have a sound network overview and is aware of what each operator is doing, operators are unlikely to be aware of disruption to each other's operations, which may have a knock-on impact.

The level of acceptance expected from the mobility actors when the specific response plans of TANGENT are implemented are described below:

It is a difficult task for the TfGM Control Centre to comment on the level of acceptance expected from the mobility actors on behalf of other organisations. In a future franchised bus market, this should be acceptable to bus operators franchised to TfGM, likewise with Keolis Amey Metrolink.

KAM already maintains a Disruption Management Plan which outlines the plan for different disruption scenarios, however, it is worth noting that this does not cover all scenarios and they frequently must step outside this plan.

National Highways and Greater Manchester Police have their response plans, processes, and procedures, and it is likely that if closures are required by either party, they will often have to dynamically change their response plan to the current situation. As such, it is my view that specific response plans enacted by a 3rd party would not be accepted by these organisations.

A description of the potential impact on the cooperation for the specific use cases that are expected from the existing and new challenges is provided below:

A network status overview, which shows and alerts all users to incidents and disruptions ongoing would be useful for sharing information. This would allow information to be input into a system once only and allow all mobility actors to gain shared situational awareness of ongoing disruptions, and therefore better manage incidents. This would require user-based access control, to ensure all details of an incident are not visible to all parties, e.g., if the incident is sensitive or security related. TfGM Control Centre staff should be able to become more efficient by reducing the amount of time informing, and more time responding to and managing an incident.

4.3.3 Stakeholder mapping

This table provides an overview of the local stakeholders and their role in each of the services and functionalities.

Sub-service	Functionality	Stakeholder type	Role	Name of the local stakeholder
TANGENT Service 1: Enhanced information service for multimodal transport management				
Real-time information	Visualise the current status of the network	Infrastructure provider - Traffic managers and PT operators	To monitor the transport network as a whole - TfGM. To monitor mode-specific operation for bus and tram	TfGM control centre Tram Metrolink Bus operators e.g., Stagecoach
Predictive Information	Visualise the future status of the network	Infrastructure provider - Traffic managers and PT operators	To identify possible congestion and disruption events in advance to allow action to manage the transport network	TfGM control centre Tram Metrolink Bus operators e.g., Stagecoach
TANGENT Service 2: Real-time Traffic Management Services				
Smart Network Load Balance	Informing the transport passengers	Infrastructure provider - Traffic managers and PT operators	To monitor the transport network across all modes. Act on info from SNLB to implement traffic management strategies, set VMS, and utilise social media and journey planning apps of incidents.	TfGM control centre Tram Metrolink Bus operators e.g., Stagecoach
Cooperative Incident Management	Synchronisation of transit and traffic	Infrastructure provider - Traffic managers and PT operators	Monitor and manage the transport network across modes, communicate info between stakeholders and act on info from COP.	TfGM control centre Tram Metrolink Bus operators e.g., Stagecoach
TANGENT Service 3: Transport network optimization for Transport Authorities				
Simulation of scenarios suggested by the decision maker		Traffic Manager TfGM Modelling team	Review output, align with real-world deployment and traffic management plans	TfGM
Generation of Response Plans		Traffic Manager TfGM Modelling team	Review output, align with real-world deployment and traffic management plans	TfGM

Table 17: Stakeholder mapping Greater Manchester

4.3.4 Traffic Management Strategies

The strategies relevant to the pilot for the city of Manchester are listed below:

- Travel behaviour management (through information provided to the user).
- Dynamic congestion pricing.
- Prioritising public transport.
- Synchronisation of traffic and public transport.
- Signal strategies in response to events.
- Travel demand management – the impact of VMS signing, communication, strategies for events.

4.3.5 Transport Modelling

4.3.5.1 Greater Manchester SATURN Model (GMSM)

The transport modes included in this model are public transport, bicycles, cars, and trucks involving 5 user classes namely Car commute, Car employers' businesses, Car (other), LGV (Light Goods Vehicles) and OGV (Other Goods Vehicles) including buses.

The Network supply consists of Traffic/Transit control plans (e.g., for AM and PM). The signals are also coded in the network with public transport lines and their respective stops and bus schedules. Buses are also coded into the network on their routes, but the model does not consider stops or dwell time.

Cycle lanes are only implicitly included, where they impact the road space/capacity for general traffic or bus.

In terms of Area, the model covers much of the UK with most details in Greater Manchester. The details decrease with a further radius away from the city. This is a macroscopic model.

For this model, Greater Manchester uses SATURN as their modelling tool which was lastly calibrated in the year 2017 and it's updated every 2 years with the latest development taking place in 2019.

The type of traffic measurements used to calibrate and validate the models include Traffic counts/ ATCs, and route journey times. The OD Matrices have aggregation periods from 8.00 - 9.00 (peak hours) in the morning, Inter peak hours from 10.00 – 16.00 and evening peak hours from 17.00 – 18.00.

4.3.5.2 Greater Manchester Aimsun Model

Greater Manchester Aimsun Model is a combination of macro, micro and mesoscopic modelling behaviours with different areas having different levels of detail. Typically, the geographical area is fed to micro or meso as part of the project work which is then fed back to the main base model. The transport modes include public transport, bicycles, cars, and trucks involving 5 user classes namely Car commute, Car employers' businesses, Car (other), LGV and OGV including buses.

The model is essentially based on the SATURN model. The Network supply consists of Traffic/Transit control plans (e.g., for AM and PM). The signals are also coded in the network with public transport lines and their respective stops and bus schedules. Buses are also coded into the network on their routes, but the model does not consider stops or dwell time.

Cycle lanes are only implicitly included, where they impact the road space/capacity for general traffic or bus.

In terms of Area, the model covers much of the UK with most utmost details in Greater Manchester. The details decrease with a further radius away from the city.

Local geographical areas are being calibrated as part of the ongoing project work and while updating, traffic counts/ATCs, route journey times and site visit observations are used. The matrices are from the 2017 GMSM and they would be updated with the 2019 SATURN model.

4.3.5.3 Regional Centre S-Paramics Model

The S-Paramics Model of Greater Manchester is essentially a microscopic model which includes the traffic modes of public transport, bicycles, cars, and trucks. User classes of car, HGV, LGV, bus and trams are included in the model. Signals are coded and the stop and dwell times of Buses are also included in the model. Metrolink trams are also included. Bicycle lanes are included as an extra where they impact the road capacity for the general traffic or bus. The area covered by the model includes the regional centre of Greater Manchester.

This model is calibrated based on traffic counts/ATCs, route journey times and site visit observations with the latest calibrated in the year 2017.

The aggregation period for the OD Matrices is the morning peak hours of 8.00-9.00 and the evening of 17.00-18.00.

The last update was in the year 2018 and there is no intention of updating it during the TANGENT project.

4.3.6 Impact canvas per TANGENT service

TANGENT Services	Objectives	Case Study Description and requirements	Target users and benefits	Expected Impact	Challenges
(1) Enhanced information service for multimodal transport management – Dashboard & API	To integrate and coordinate data and actions for more efficient network management providing an overview of transport modes and status of the network in an easily accessible visual, bringing real-time data together in one dashboard. This will provide decision support tools for control centre operators and speed up operator assessment of incidents and related interventions. Will assist communication and action between modal operators.	Tram Bus Highway Active travel Strategic road network (Motorways)	Frontline operational teams from Bus stations/Interchanges Control rooms from each agency Transport users Bus operators Tram operator National Highways TfGM control centre will be the focal point. Oversight of all modes will assist highway operation, consequently impacting all modes.	Making better use of existing modes Bus tram-trains Re-routing for incident management Influence modal choice/timing of the journey More reliable journeys and better customer experience More reliable data will drive customer confidence automation of customer information (e.g., journey time data/car park data on VMS) Integration of data across modes makes the whole customer journey more seamless The Above assist more strategic goals of Reducing congestion, Improving use of	Data availability /sharing and Data accuracy Ability to manage the data in meaningful user-focused ways. Promoting behaviour change How to prioritise geographical scope/priority's locations Emerging technologies – futureproofing Accuracy of response plans Minimising risks of flawed data - Inaccurate Algorithms Incorrect information goes into the system - How do we validate it? E.g., CCTV, Bus operators, Waze, other observations

TANGENT Services	Objectives	Case Study Description and requirements	Target users and benefits	Expected Impact	Challenges
				sustainable transport modes and Carbon reduction	
(2) Real-time Traffic Management Services	This will allow TfGM to better manage the transport network across differing situations, taking into account of multimodal journeys. Will support coordination of transport services to promote seamless journeys across modes. Improve traffic flows and reduce the impact of congestion and disruption on the transport network. SNLB will support more sustainable journeys. Improved incident management. Minimise disruption and congestion during incidents and events. Focus on all stakeholders and collaboration will improve multimodal operation.	Tram Bus Highway Active travel Strategic road network	Frontline operational teams from Bus stations/Interchanges Control rooms from each agency Transport users Bus operators Tram operator National Highways TfGM control centre will be the focal point. Oversight of all modes will assist highway operation, consequently impacting all modes	Better integration between modes. Improve journey times and customer experience - based on the information given to customers on their journeys. Suggestions on alternatives based on real-time reliable data. Rerouting for incidents. The Above assist more strategic goals of Reducing congestion, Improved use of sustainable transport modes and Carbon reduction.	Behaviour change - will passengers act on advice given? How do we measure? Cooperation between organisations - modes want the best for their service rather than a whole network view. Competing/conflicting priorities of network users/actors incomplete data, known unknowns Co-operating between private and public Data availability The ability of the system to handle data, integrate and optimise for all modes.

TANGENT Services	Objectives	Case Study Description and requirements	Target users and benefits	Expected Impact	Challenges
	Exploration of the benefits of strategies - re-routing, signal timing changes, nudges for modal shift. An output of Journey times across modes could be sent out as an alert to promote the use of PT and P&R.				
(3) Transport network optimization for Transport Authorities	Understand how future mobility and transport systems can assist people's movement across GM. Assist with scenario planning and optimisation of the network. Simulate near to real-term scenarios to realise the biggest benefits for GM. This service will also enhance the existing modelling capabilities within TfGM to consider future mobility rather than just the current situation.	Tram Bus Highway Active travel including bike hire and e scooters Strategic road network Rail First and last mile services operating alongside the existing PT network Demand responsive transport Provision of P&R and impact	TfGM modelling team, network managers and Innovation, Strategy and Policy	Evidence bases for the implementation of traffic control strategies and optimisation within service 2. Understanding and promoting future mobility systems. Reducing congestion. Improved use of sustainable transport modes. Carbon reduction.	Meaningful scenario development for TfGM. Communicating output - ensuring output can be used in future policy and strategy. Make sure modelled simulations align with existing techniques for modelling future transport scenarios. Managing existing demand matrices.

Table 18: Impact Canvas for Greater Manchester

4.3.7 Scope and Scenarios definition per TANGENT Services

TANGENT Service 1: Enhanced information service for multimodal transport management							
Sub-Service	**Functionality**	**Objectives**	**Scope: Virtual or Real (where?)**	**Baseline Scenario**	**Planned Event(s)**	**Unplanned Event(s)**	**Future Scenario(s)**
Real-time information	Visualise the current status of the network	One view of the transport network for all modes. Current network status and real-time traffic condition mapped user interface, layer tabs, drill down to get actual data with main view RAG visual. Disruptions and congestion hotspots flagged.	Real - onsite Control centre environment	Daily commuter travel - normal traffic conditions.	Concerts, football matches, major roadworks. Public transport strike.	Unplanned roadworks, road traffic collision - closing roads, minor disruption blocked the highway, motor incidents and diverted traffic,	
Predictive Information	Visualise the future status of the network	One view of the transport network for all modes. Future network status and predicted traffic conditions. Impact of Disruptions and congestion hotspots flagged.	Real - onsite Control centre environment	Daily commuter travel - normal traffic conditions.	Concerts, football matches, major roadworks. Public transport strike.	Unplanned roadworks, road traffic collision - closing roads, minor disruption blocked the highway, motor incidents and diverted traffic	

Table19: Scope and Scenarios definition for Service 1 for Manchester.

TANGENT Service 2: Real-time Traffic Management Services							
Sub-Service	**Functionality**	**Objectives**	**Scope: Virtual or Real (where?)**	**Baseline Scenario**	**Planned Event(s)**	**Unplanned Event(s)**	**Future Scenario(s)**
Smart Network Load Balance	Informing the transport passengers	Provide customer information on disruption, congestion and incidents through agreed channels, VMS, social media, Waze for Cities, other partners – for public transport. Information communication should be on disruption events and current network status with mode information to the most suitable options and response plans	Real-control centre environment	Optimisation of network based on journey time across modes, for the daily commuter travelling under normal traffic conditions.	Concerts, football matches, major roadworks. Public transport strike.	Unplanned roadworks, road traffic collision - closing roads, minor disruption blocked the highway, motor incidents and diverted traffic.	
Cooperative Incident Management	Synchronisation of transit and traffic	How will bus/tram priority assist network management and modal shift? Assessment of the efficiency for different modes and traffic conditions in selected areas. To include proposed	Virtual	Simulated mobility scenarios for different times of day and under various conditions (severe congestion, incidents etc.) for synchronisation and no synchronisation between transit and traffic situations.	Concerts, football matches, major roadworks. Public transport strike.	Unplanned roadworks, road traffic collision - closing roads, minor disruption blocked the highway, motor incidents and diverted traffic.	

TANGENT Service 2: Real-time Traffic Management Services							
Sub-Service	**Functionality**	**Objectives**	**Scope: Virtual or Real (where?)**	**Baseline Scenario**	**Planned Event(s)**	**Unplanned Event(s)**	**Future Scenario(s)**
		TfGM Quality Bus Corridors Evaluation of behaviour and mode changes.					

Table 20: Scope and Scenarios definition for Service 2 for Manchester.

TANGENT Service 3: Transport network optimization for Transport Authorities							
Sub-service	**Functionality**	**Objectives**	**Scope: Virtual or Real (where?)**	**Baseline Scenario**	**Planned Event(s)**	**Unplanned Event(s)**	**Future Scenario(s)**
Simulation of scenarios suggested by the decision maker	What-if scenario 1: Parking Guidance Enhanced Redirecting vehicles to unoccupied off-street/on-street parking More Park&Ride locations including Metrolink and rail stations	Impact on traffic flow and congestion with increased parking guidance Assessment of changes in the modal split as a result of increased access to park and ride options.	Virtual	Simulated traffic flows at various locations and times of day with and without park recommendations, for the daily commuter travelling under normal traffic conditions.	Concerts, football matches, major roadworks. Public transport strike.	Unplanned roadworks, road traffic collision - closing roads, minor disruption blocked the highway, motor incidents and diverted traffic.	

TANGENT Service 3: Transport network optimization for Transport Authorities							
Sub-service	**Functionality**	**Objectives**	**Scope: Virtual or Real (where?)**	**Baseline Scenario**	**Planned Event(s)**	**Unplanned Event(s)**	**Future Scenario(s)**
	What-if scenario 2: On-demand and scheduled first and last mile services operating alongside the existing PT network	Impact on traffic flow and congestion if PT is enhanced by on-demand and first, last mile services	Virtual	Simulated traffic flows at various locations and times of day with and without on-demand and first/last mile services for the daily commuter travelling under normal travel conditions.	Concerts, football matches, major roadworks. Public transport strike.	Unplanned roadworks, road traffic collision - closing roads, minor disruption blocked the highway, motor incidents and diverted traffic.	
	What-if scenario 3: What if cycle hire and micro-mobility were increased - link to transport hubs How can C ITS be utilised to improve safety and efficiency for riders	Impact on network management with increased cycle hire and micro-mobility for commuter and cross-city journeys. implication of CITS on safety and efficiency for riders	Virtual	Simulated rides, pickups, stops and docks of cycle hire and e-scooter at various locations and times of the day under normal traffic conditions – cross-city trips Manchester Oxford Road to Media City.	cross-city trips from Manchester Oxford Road to Media City	Road closure impacting routes	

Table 21: Scope and Scenarios definition for Service 3 for Manchester.

4.3.8 Visualisation and Interaction

	Description of the data	Potential Data Source / Stakeholder	Expected Visualisation
Data from Existing Data-sources	Bus real-time supply	Central gov - open data	Live bus real-time location in a geographic map. Live updated. Some details about each bus when passing the mouse over the bus icon.
	Tram real-time supply	network operator - TfGM	Live next tram information, the status of network for tram - red, amber, green on-map at each location.
	Real-time traffic counters	Network manager TfGM	Visualisation of traffic flows updated with new data every 5 minutes. Traffic flows states are represented by a red to green colour shade over the roads. Lanes and directions are distinguishable when zooming in.
	Journey time for routes	Network manager TfGM	Visualisation of journey time updated with new data every 5 minutes. Traffic flows states are represented by a red to green colour shade over the roads. Lanes and directions are distinguishable when zooming in. Deviation from normal journey time can be displayed.
	Events, incidents, and roadworks	Network manager TfGM	Location of events/incident mapped, detail when happened and expected impact and duration, any response plans in place - would be text-based info from operators
	Traffic management assets - CCTV, sensors, traffic signals, VMS	Network manager TfGM	Mapped Location of assets to allow operators a quick view of what tools they have available in the location they are viewing. e.g., if there is congestion on a route then they use the tools available to verify.
Predictive Information	Traffic flow prediction	2h ahead prediction model from Tangent predictions' module	Visualisation of traffic flows equivalent to the Live one (above). A timeline should be visible to show the available period with predictions and it should be clear that the viewed data is not live but a prediction. Predicted network status should be colour coded and the expected duration should be presented.
	Public transport patronage prediction	2h ahead prediction model from Tangent predictions' module	Visualisation of increased patronage by mode - demand has increased due to events, and disruption on other modes. Predicted network status should be colour coded and the expected duration should be presented.

	Description of the data	Potential Data Source / Stakeholder	Expected Visualisation
	Disruption events/incidents	Road operator, TANGENT Services	Visualisation of disruption event and predicted impact mapped. Expected Duration should be presented.
Alerts / Notifications	E.g.: the Bus network is becoming overflowed in a specific area	E.g.: Bus operator	E.g.: A notification appears on the Dashboard stating that the Bus network is suffering from supply shortages in a specific city area (name) and how much above capacity demand is now (e.g., 145%). The notification links to a map visualisation of the Bus real-time supply data.
	E.g.: Traffic congestion (from radars/traffic counters)	E.g.: Road operator	E.g.: Alert showed on the map as a conge marker/icon. It happens when certain KPI or LoS are not met (the average speed for a stretch is lower than the given threshold or the vehicle is higher than a given threshold.)
	Flag for disruption events/incident	Road operator, TANGENT Services	Visualisation of disruption event and predicted impact mapped. Expected Duration should be presented.
Cooperative Operational Scenarios	E.g.: During a large event it is necessary to increase public transport capacity	E.g.: Bus operator, metro operator, road operator	E.g.: In the dashboard, there should be a notification stating the need for cooperation between the 3 parties. The notification should state the identified need for an increase of PT capacity, the origin of this need (e.g., KPI or LoS is not met) and the parties involved. There should be a link to see a graphic map visualisation showing evidence related to this situation and there should be a work area for the 3 parties to define the approach to this problem (e.g.: define the level of increase of supply from a bus - 0% to 50%, from the metro and define the prioritisation level of traffic lights - 0% to 30%). A commit button should be available to finalize the decision from all parties involved.
	Response plan proposal	TANGENT services	Suggest signal strategies, customer information, rerouting
	Alternative mode suggestion	TANGENT services	Real-time journey times across modes. Live journey time, information taxi = 50min, info bus & tram = 45min, info train = 30min to promote alternative mode. E.g., P&R would be 10 min quicker than driving to the city centre

	Description of the data	Potential Data Source / Stakeholder	Expected Visualisation
Other inputs for decision making	E.g.: the Bus network is becoming overflowed in a specific area	E.g.: Bus operator	E.g.: In the dashboard, there should be a notification stating the need for a decision from the Bus operator. The notification should state the identified need for an increase of PT capacity, the origin of this need (e.g., KPI or LoS is not met) and the party involved (bus operator). There should be a link to see a graphic map visualisation showing evidence related to this situation and there should be a work area for bus operators to define the approach to this problem (e.g.: define the level of increase of supply from the bus - 0% to 50%). A commit button should be available to finalise the decision from the bus operator.

Table 22: Visualisation and Interaction preferences for Greater Manchester.

4.4 Athens

4.4.1 Local context

4.4.1.1 Mobility and policy context

The key mobility priorities for the city of Athens are the improvement of the network connectivity and operation, reduction in emissions, accidents and congestion, and prioritisation of public transport and soft modes.

The TANGENT services for the case of Athens will be tested in the inner ring of Athens' city centre. using AIMSUN simulation platform.

Problems that Athens faces include severe congestion, lack of coordination between different modes, pollution, accidents, and an overrepresentation of private vehicles in commuting patterns.

4.4.1.2 Introduction of new travel alternatives

Mobility services that will be of interest for Athens include first and last-mile services operating alongside the existing PT network, on-demand vehicles serving less dense areas within the Athens Metropolitan Area and CAVs operating on dedicated lanes or alongside traffic, as they mature technologically.

4.4.2 Characterisation of the transport network in terms of modes, data sources and governance

4.4.2.1 Transport Modes and Services

Athens is served by several different public transport modes: buses and trolley buses, metro, tram, and suburban rail, which are run by different operators. An extensive bus and trolley bus network, consisting of about 260 bus routes and 19 trolley bus routes, operates in the city of Athens covering most of Athens's metropolitan area. Buses and trolleybuses in Athens are mainly operated by OSY, a wholly owned subsidiary of state-owned Athens Transit (OASA S.A.). The latter also acts as the Transport Authority for the city of Athens, being responsible for the strategic and operational planning, coordination and control of the public transport carried out by public transport means in the Attica Region. Approximately 10% of the network is operated by KTEL, a private consortium of bus owners (KTEL). The Athens metro system has 3 lines serving 64 stations. The lines pass through the centre of Athens and connect it with various suburbs, the port of Piraeus and the airport. The tram links the centre of Athens with the port of Piraeus, Faliro, a south area next to Piraeus, and the southern suburb of Voula. Both the metro and tram systems are operated by Urban Rail Transport (STASY), a wholly owned subsidiary of Athens Transit. The suburban rail line connects the airport with the city centre of Athens and the port of Piraeus. It is managed by TrainOSE, a private railway company which operates rail services throughout the Greek railway network.

For the implementation of the TANGENT tool, public transport modes should be prioritised versus private vehicles. In addition, some space should be rendered for soft modes as well.

4.4.2.2 Transport Infrastructure

The Traffic Management Centre operating under the auspices of the Athens Region has approximately 550 measuring stations for traffic data (simple on-road inductive loop detectors and "mechanical vision" loops), 217 traffic surveillance cameras, 24 Variable Message Signs, a complete traffic monitoring system (SITERFF) regulator, as well as 850 traffic controllers at signalised junctions. Similar equipment is also controlled by Attiki Odos S.A., which operates under the concession of a tolled highway within the city limits. Real-time information for buses and trolleybuses is recorded using the onboard GPS sensors of vehicles and shared with the public by Athens Transit via the OASA Telematics App or the corresponding API.

4.4.2.3 Overview of data sources

Further information on data sources can be found in the deliverable D2.1 will develop this further.

4.4.2.4 Characterisation of governance

The Athens pilot is a virtual pilot meaning that once the priorities for the city are already known, we can assume that the relevant stakeholders would accept all possible solutions proposed within TANGENT, and therefore we will test a variety of solutions within the simulation.

4.4.3 Stakeholder mapping

This table provides an overview of the local stakeholders and their role in each of the services and functionalities.

Functionality		Stakeholder type	Role	Name of the local stakeholder
TANGENT Service 1: Enhanced information service for multimodal transport management				
Real-time Information	Visualise the current status of the network	Authority	Traffic Manager	Traffic Management Center of the Region of Attica
		infrastructure provider	Traffic Manager of the tolled Athens Beltway	Traffic Management Centre of Attiki Odos
		Authority	Transport Authority	OASA S. A
		Public transport Operators	Operator for part of the bus network	OSY S. A
		Public transport operators	Operator for part of the bus network	KTEL S. A
		Public transport operators	operator of the Metro Network	STASY S. A
Predictive Information	Visualise the future status of the network	Authority	Traffic Manager	Traffic Management Center of the Region of Attica
		infrastructure provider	Traffic Manager of the tolled Athens Beltway	Traffic Management Centre of Attiki Odos
		Authority	Transport Authority	OASA S. A
		Public transport operators	Operator for part of the bus network	OSY S. A
		Public transport operators	Operator for part of the bus network	KTEL S. A
		Public transport operators	Operator of the Metro Network	STASY S. A
TANGENT Service 2: Real-time Traffic Management Services				
Smart Network	Informing the transport passengers	Authority	Traffic Manager	Traffic Management Centre of the Region of Attica

Functionality		Stakeholder type	Role	Name of the local stakeholder
Load Balance		Authority	Local Government	Municipality of Athens
		Authority	Transport Authority	OASA S. A
		Authority	Civil Protection Agency	General Secretariat for Civil Protection
	Dynamic congestion pricing	Authority	Local Government	Municipality of Athens
		Authority	Transport Authority	OASA S. A
		Authority	Regional Government	Region of Attica
		Authority	Traffic Manager	Traffic Management Centre of the Region of Attica
	Adaptive Traffic Control and CAVs	Authority	Traffic Manager	Traffic Management Centre of the Region of Attica
		Authority	Traffic Police	Traffic Police of Attica
Cooperative Incident Management	Synchronisation of transit and traffic	Authority	Traffic Manager	Traffic Management Centre of the Region of Attica
		Authority	Transport Authority	OASA S. A
		Public transport operators	Operator for part of the bus network	OSY S. A
		Public transport operators	Operator for part of the bus network	KTEL S. A
	Synchronisation of on-demand and transit modes	Authority	Transport Authority	OASA S. A
		Public transport operators	Operator for part of the bus network and possible operator of future on-demand services.	OSY S. A
		Public transport operators	Operator for part of the bus network and possible operator of future on-demand services.	KTEL S. A
		Public transport operators	Operator of the Metro Network.	STASY S. A
TANGENT Service 3: Transport network optimization for Transport Authorities				
	Simulation of scenarios suggested by the decision maker	Authority	Traffic Manager	Traffic Management Centre of the Region of Attica

Functionality		Stakeholder type	Role	Name of the local stakeholder
		Authority	Transport Authority	OASA S. A
	Generation of Response Plans	Authority	Traffic Manager	Traffic Management Centre of the Region of Attica
		Authority	Transport Authority	OASA S. A

Table 23: Athens Stakeholder Mapping

4.4.4 Traffic Management Strategies

1. Dynamic congestion pricing
2. Prioritising public transport
3. Synchronisation of traffic and public transport
4. On-demand services (integration and synchronisation with public transport)

4.4.5 Transport Modelling

In the city of Athens, the "Athens Testbed" has been developed by NTUA. Athens Testbed is a custom-made hybrid model which includes a macroscopic travel demand model for the larger metropolitan area of Athens, as well as a microscopic traffic simulation model for the Athens inner-ring urban transportation network.

Demand-wise, at the macro level, an Origin-Destination (OD) matrix with 1284 x 1284 dimensions exists, which covers the 24h demand of the larger metropolitan area of Athens. Said OD matrix leads to approximately 7.5 million trips. At the micro level, the OD matrix for the larger metropolitan area of Athens has been traversed and a 292 x 292 OD matrix with demand information for the peak hours has been calculated. The peak-hour OD matrix for the micro network leads to approximately 83000 trips.

Figure 15: The Athens metropolitan area and the inner ring (marked red)

Athens Testbed is a hybrid model meaning that both a macroscopic (larger metropolitan area of Athens) and a microscopic (Athens's inner-ring urban transportation network) model are implemented. The figures illustrate Athens Testbed with the detailed network of the inner ring. Mixed traffic flow conditions are simulated in the Athens testbed.

The modes of transport used are passenger cars, trucks (heavy vehicles in general with high PCUs) and public transportation. Pedestrian or bicycle flows, as well as the Athens metro network, are not yet incorporated. 440 signalised intersections with detailed traffic light schedules are included in the simulation. 330 bus lines & 5855 bus stops are available for the macro level and 148 bus lines & 615 bus stops micro level. The macroscopic model covers the larger metropolitan area of Athens. The network is composed of 7040 nodes and 15827 edges. The microscopic model covers the Athens city centre, and the network is composed of 1293 nodes and 2572 edges

Figure 16: The inner ring of the Athens testbed in the simulation software

Athens Testbed offers a suite of software and tools for the analysis of the urban transportation network of Athens. The Athens Testbed comprises a detailed representation of the network in four (4) different software and platforms. At first, the larger metropolitan area of Athens is maintained in GIS software, which includes all the necessary attributes (edges, intersections, number of lanes, etc.) for the urban transportation network of Athens. Additionally, the larger metropolitan area of Athens (both the macro and micro level) is maintained in the Aimsun Next traffic simulator (https://www.aimsun.com/aimsun-next/). Concerning the microscopic simulation / Athens inner-ring urban transportation network, the Eclipse SUMO micro simulator (microstimulator https://www.eclipse.org/sumo/) also contains a well-defined and well-calibrated version of the network. Last, the NetworkX python package is used as the graph analysis tool for the micro network of Athens Testbed.

4.4.6 Impact canvas per TANGENT service

TANGENT Services	Objectives	Case Study Description and requirements	Target users and benefits	Expected Impact	Challenges
(1) Enhanced information service for multimodal transport management – Dashboard & API	This service is irrelevant for the virtual Case study of Athens, due to lack of participation of stakeholders who will access the relevant data through the Dashboard				
(2) Real-time Traffic Management Services	This is the core TANGENT Service. Successful implementation which will lead in the optimization of transport network operations in both business-as--usual scenarios and in the case of planned or unplanned events.	All aspects of the urban road network should be considered, including car traffic and public transportation. Additional new services referring to micromobility and on-demand services introduced in TANGENT are also relevant for the Athens case study.	Stakeholders that will use Service 2 to optimize transport network performance include traffic managers, PT operators and authorities. Stakeholders that will indirectly benefit from better transport network performance also include citizens and emergency respondents.	Service 2 will help reaching the global targets and KPIs of Athens for the TANGENT project, which include reducing congestion, road accidents and pollution, and promote a modal shift towards public transport. (See table below for the detailed KPIs)	Issues in the flow of data necessary for monitoring of the network to identify incidents and network responses Potential integration issues of TANGENT solutions to the Athens simulation testbed (Compatibility with AIMSUN software, etc.). Issues referring to the optimisation of different sub-services (complexity, computational load etc.)

TANGENT Services	Objectives	Case Study Description and requirements	Target users and benefits	Expected Impact	Challenges
(3) Transport network optimization for Transport Authorities	This service will complement the modelling & simulation capabilities that already exist in Athens.	Complete view of transit offer, including private modes, public transit modes, on-demand and shared mobility and bicycle and pedestrian flows.	Relevant local stakeholders mainly include traffic managers, PT & shared-mobility operators, emergency respondents.	Service 3 can increase awareness on the impact of different policies on the transport network, the optimal of which will be implemented by Service 2.	Same as Service 2.

Table 24: Impact canvas per TANGENT service.

Quantified KPIs for estimating the impact on the objectives for the case of Athens

Objectives / Priorities	Key Performance Indicators (KPIs)
Congestion Reduction	Reduce travel times by 10% at peak hours Decrease speed variability by 10%
Pollution Reduction	Reduce vehicle CO2 emissions by 5% in total and by 12% during peak hours
Accident Reduction	Reduce the number of accidents by 2%
Behavioural (and mode) changes	Increase transit use by 9% on average Decrease car use by 15% in the city centre

Table 25: Key Performance Indicators proposed by Athens to be used for estimating the impact.

4.4.7 Scope and Scenarios definition per TANGENT Services

TANGENT Service 1: Enhanced information service for multimodal transport management							
Sub-service	**Functionality**	**Objectives**	**Scope: Virtual or Real**	**Baseline Scenario**	**Planned Event(s)**	**Unplanned Event(s)**	**Future Scenario(s)**
Real-time information	Visualise the current status of the network	Complete, real-time depiction of traffic conditions, modes of transport and planned or unplanned events and incidents.	Virtual	The current status of the network is displayed on the Dashboard (no incidents)	Roadworks block certain streets in downtown Athens.	Traffic accidents	
Predictive Information	Visualise the future status of the network	Complete depiction of traffic conditions, modes of transport and planned or unplanned events and incidents for multiple time horizons	Virtual	The future status of the network is displayed on the Dashboard (no incidents)	A large event is scheduled at the outskirts of the city.	A strike deviating from its course.	

Table 26: Scope and Scenarios for Service 1 for Athens.

TANGENT Service 2: Real time Traffic Management Services							
Sub-service	**Functionality**	**Objectives**	**Scope: Virtual or Real**	**Baseline Scenario**	**Planned Event(s)**	**Unplanned Event(s)**	**Future Scenario(s)**
Smart Network Load Balance	Dynamic congestion pricing	Evaluation of emissions and congestion patterns inside and around the congestion pricing areas. Assessment of changes in the modal split as a result of pricing.	Virtual	Simulated traffic flows inside and around the city centre under different circumstances (peak hours, incidents etc).	Road and/or area closures.	Incidents or natural hazards resulting in street and/or area closures.	Simulated traffic flows inside and around the city under various congestion pricing schemes.
	Adaptive Traffic Control and CAVs	Assessment of the impact of CAVs in traffic and mode choices for different penetration rates and rights of way (dedicated lanes, mixed traffic conditions etc.)	Virtual	Simulated mobility scenarios without CAVs	An example of planned event is a roadwork situation rendering a portion of a network unavailable.	Examples of unplanned events include accident or adverse weather conditions, which restrict access to specific road segments or areas or malfunctions of the CAV system, causing disruptions in traffic.	Simulated future mobility scenarios where CAV route is optimized using re-routing adaptive traffic control strategies. CAVs operate alongside normal traffic or on dedicated lanes.

TANGENT Service 2: Real time Traffic Management Services							
Sub-service	**Functionality**	**Objectives**	**Scope: Virtual or Real**	**Baseline Scenario**	**Planned Event(s)**	**Unplanned Event(s)**	**Future Scenario(s)**
Cooperative Incident Management	Synchronisation of transit and traffic	Assessment of the impacts of transit and traffic synchronisation, public transit efficiency for different modes and traffic conditions in selected axes/areas. Evaluation of behaviour and mode changes.	Virtual	Simulated mobility scenarios for different times of day and under various conditions (severe congestion, incidents etc.). No synchronisation. between transit and traffic.	Planned roadworks render specific streets unavailable. Buses are diverted away from the blocked or congested segments.	A road accident blocks a central axis in the city centre. Bus lines are automatically diverted to a parallel axis.	Simulated future mobility scenarios where transit operations and traffic are synchronised.
	Synchronisation of on-demand and transit modes	Impact assessment of on-demand and transit synchronisation across different criteria (choice of mode, pollution, congestion etc.)	Virtual	Simulated mobility scenarios under different circumstances without on-demand and transit synchronization	A large event is planned at an area without direct access to public transport. On-demand modes synchronize	An incident disrupts suburban rail operations between two stations. On demand modes temporarily assure the connection between the stations.	Simulated mobility scenarios under different circumstances with on-demand and transit synchronization

TANGENT Service 2: Real time Traffic Management Services							
Sub-service	**Functionality**	**Objectives**	**Scope: Virtual or Real**	**Baseline Scenario**	**Planned Event(s)**	**Unplanned Event(s)**	**Future Scenario(s)**
					with arrivals at the closest metro rail station to transport attendees to the event.		

Table 27: Scope and Scenarios for Service 2 for Athens

TANGENT Service 3: Transport network optimization for Transport Authorities							
Sub-service	**Functionality**	**Objectives**	**Scope: Virtual or Real**	**Baseline Scenario**	**Planned Event(s)**	**Unplanned Event(s)**	**Future Scenario(s)**
Simulation of scenarios suggested by the decision maker	What-if scenario 1: Implementation of congestion pricing schemes	Reduce emissions and congestion in the city centre	Virtual	Introduce a congestion pricing schemes in the inner ring of Athens	Non recurrent incidents / events (rallies, work zones etc) and road closures	Extreme events (climate change scenarios) and pandemics	Urban regeneration interventions (e.g., pedestrianization of roads)

Table 28: Scope and Scenarios for Service 3 for Athens

4.4.8 Visualisation and Interaction

	Description of the data	Potential Data Source / Stakeholder	Expected Visualisation
Data from existing Data Sources	Bus lines and stops	Bus operator	Visualisation of bus lines as color-coded lines on a geographic map and depiction of stops.
Data from existing data-sources	PT stations	Bus operators	Clicking on PT station on a geographical map displays vehicles and vehicle paths of PT lines serving the station
Predictive information	Road equipment positions	Traffic managers, authorities, and various levels of government	Positions of traffic loops are depicted as objects on a geographical map. Hovering over with the mouse results in the display of relevant information (e.g., traffic counts or speeds).
	Road pricing schemes	TANGENT service output	A layer that can be superimposed on other maps contains the areas or corridors under a pricing scheme. Clicking on the area or corridor displays current and future pricing.
Predictive information	Planned events and incidents	Simulation output	Visualisation of incidents as polygons analogous to the incident extent. Impacted segments are shown in red when viewed alone or in grey when superimposed to the traffic flow maps.
Alerts / Notifications	Planned events or incidents in a specific area	Traffic managers, authorities, PT operators	A general overview of future planned events network disruptions is available at a dedicated area of the dashboard. Every event is associated with a colour-coded impact assessment, based on, for example, historical data. Clicking on an incident lead to a dedicated page with a detailed overview of the situation, a step-by-step mitigation strategy, the recommended response plans, a list of involved stakeholders, successful past strategies for solving similar problems etc. Events and incidents can also be visualised individually on top of a geographical map.
	Unplanned events or incidents in a specific area	Traffic managers, authorities, PT operators, first responders	Unplanned events are presented in a similar way to planned events, with special attention being paid to informing stakeholders and enhancing communication between them. Notifications on incidents can be more intrusive (through pop-up banners, audio alerts). Stakeholder interaction is facilitated by displaying the

	Description of the data	Potential Data Source / Stakeholder	Expected Visualisation
			contact information of relevant stakeholders (contact person and way of reaching her, telephone numbers etc.).
Cooperative Operational Scenarios	E.g.: During a large event it is necessary to increase public transport capacity	E.g.: Bus operator, metro operator, road operator	E.g.: In the dashboard there should be a notification stating the need for cooperation between the 3 parties. The notification should state the identified need for an increase of PT capacity, the origin of this need (e.g., KPI or LoS is not met) and the parties involved. There should be a link to see a graphic map visualisation showing evidence related with this situation and there should be a work area for the 3 parties to define the approach to this problem (e.g.: define the level of increase of supply from bus - 0% to 50%, from metro and define the prioritisation level of traffic lights - 0% to 30%). A commit button should be available to finalise the decision from all parties involved.
	Consensus elicitation	Traffic managers, authorities, PT operators, first responders	In the case that a consensus among stakeholders is required, a dashboard link leads to the consensus-reaching mechanism. Stakeholders state their preferences with respect to different objectives through a voting process, where stakeholders provide input to the consensus mechanism by inserting preference data to the corresponding data entry forms. At each stage of the process, the mechanism notifies stakeholders on the degree of consensus and the optimal response plans based on their preferences via the corresponding messages on the dashboard. Stakeholders have to validate the final response plan.

	Description of the data	Potential Data Source / Stakeholder	Expected Visualisation
	Response plan rendering		The effects of applying a specific response plan to a given situation are depicted on top of a geographic map. A sequence of maps (think of.gif images or videos), captures the impact of the response plans over different time horizons. Maps of forecasted network effects follow the same codification as real-time maps (e.g., colour-coded links representing future traffic flows). Metrics and attributes (average travel time, time to return to normal etc.) of different response plans are also represented together on a MxN matrix (M response plans with N attributes each). Response plans are ranked based on their capacity to mitigate the given situation. The best/worst values of each attribute column are displayed in shades of green or red respectively (Table).
	Resolution of a planned or unplanned event.		After the resolution of an event, the applied response plan is rated for its mitigatory capacity. All ratings of event-response plan pairs are documented for future reference and analysis. Successful response plans are automatically proposed in similar future events. Stakeholders can also attach comments for future reference.

	column 1	column 2	column 3	column 4	column 5	column 6	column 7	column 8
row 1	-980	-169	889	-286	-778	-1127	-1018	-818
row 2	666	1495	-464	1663	586	817	-1941	1946
row 3	1068	789	-210	-336	-1785	-1468	1542	70
row 4	1242	1377	1286	282	1481	-80	1035	704
row 5	-1181	486	-545	1150	1549	-561	457	-313
row 6	-1568	-885	1489	562	-228	1238	-854	-844
row 7	-1764	-787	764	911	1842	336	-944	1979
row 8	-1316	-467	1229	-61	-1681	-1261	653	-1347
row 9	-403	1021	-757	-1411	-737	1191	1656	1535
row 10	-1549	1498	490	-1482	1147	-263	-318	1291
row 11	-1376	547	-935	-761	422	-844	1443	1373
row 12	-610	77	708	1340	1965	360	1350	178
row 13	-1626	1577	-243	953	1200	-862	-230	827
row 14	1698	1380	-1506	1598	1614	716	-1201	677
row 15	576	1441	19	1033	1473	-1052	1149	-1077
row 16	1183	26	-128	-1018	1919	1269	1359	-811

Table 29: Visualisation and Interaction Preferences for Athens.

5 Final list of requirements

As shown in the table in Annexe 8 a final list of general and specific system requirements was created for each service and functionality of the TANGENT platform. Each of the requirements shown was defined based on the description of the services shown in Chapter 0, the questions included in the Service Requirement template described in Chapter 0 and the information provided in the use cases described in Chapter 1.6.2. As can also be seen in the table, each of the system requirements was assigned an identifying code to ensure traceability throughout the project and a typology to identify whether it was functional or non-functional. Finally, each system requirement was also assigned a priority according to the feedback received in the Workshops, in the Service Requirement templates and the Use Cases. The three priority levels established were:

- Essential: The requirement must be implemented regardless of costs and is necessary for the success of the system.
- Optional: The requirement does not necessarily have to be implemented. The omission of several optional requirements does not affect the success of the system being created.
- Desirable: Requirements that do not affect the success of the system being created if they are not implemented.

In the following table, the system requirements (SRs) collected for TANGENT are summarised in a quantitative way. More specifically, both for general system requirements and for each of the services and functionalities of TANGENT, the table shows the total number of system requirements that have been collected, as well as this number disaggregated by type (Functional [F], Non-Functional [NF]) and by priority (Essential [E], Optional [O], Desirable [D]).

As can be seen at the end of the table, a total of 154 system requirements have been collected, 94% of which are functional and 6% non-functional. If we look at their priority, 39% of them are essential, i.e. their implementation is necessary for the success of the system. As for the number of optional and desirable requirements, they represent 18% and 43% respectively. The relatively high percentage of desirable system requirements is due to the fact that the strategy followed for their definition has been to provide a wide range of services and functionalities, with the aim of maximising the number of functionalities that are of interest to the stakeholders involved in transport network management and to the case studies defined for TANGENT. Given that some functionalities were not of interest to the stakeholders who participated in the workshops and/or for the case studies, or were technically not feasible, their associated requirements have been marked as desirable, as their implementation would not be a priority.

As for Service 1, we see that it has a high percentage of essential requirements (53%), as both functionalities had a high interest for stakeholders and use cases. If we look at Service 2, the number of essential requirements drops to 24%. This is mainly due to the functionalities "Synchronisation of on-demand and public transport" and "Adaptive Traffic Control with CAVs", which have all their requirements marked as desirable, as the interest in them was low. The main reason was the low implementation of the transport modes considered for these functionalities (Demand Responsive Transport and CAVs) in the case studies (with the exception of Athens which is a virtual use case). Finally, Service 3 also has a high percentage of essential requirements due to its importance for the stakeholders and for the use cases, particularly the functionality "Common Operational Picture generation support tool".

TANGENT Service	TANGENT Subservice	TANGENT Functionality	Total Num. of SRs	Number of SRs by type		Number of SRs by priority		
				F	NF	E	O	D
General System Requirements			13	6	7	3	0	10
Service 1 - Dashboard		Current State	16	16	0	11	0	5
		Future State	20	20	0	8	7	5
	Total		36	36	0	19	7	10
Service 2 - RT Traffic Management	Cooperative Incident Management	Sync traffic control and PT	10	9	1	6	0	4
		Sync On-Demand and PT	14	14	0	0	0	14
	Network Load Balance	Informing Transport Passengers	18	17	1	5	5	8
		Dynamic Congestion Pricing	8	8	0	3	3	2
		Adaptive traffic Control and CAVs	9	9	0	0	0	9
	Total		59	57	2	14	8	37
Service 3 – Transport network optimization for Transport Authorities		Common Operational Picture generation support tool	25	24	1	17	6	2
		Response plan generation tool	10	10	0	2	3	5
		Simulation of pre-defined scenarios	9	9	0	3	4	2
	Total		44	43	1	22	13	9
Total			154	144	10	60	28	66

Table 30: Quantitative summary of system requirements collected

6 Conclusions

This document aimed at identifying the system requirements for the TANGENT functionalities for each case study, based on a detailed definition and description of each case study and a comprehensive consultation and engagement process with local stakeholders. In this way, it reported on the evaluation of stakeholders' needs and the analysis of the requirements of the local transport network for the architecture definition, design, and operation of TANGENT services for advanced traffic and network management. To this end, each case study has further defined the needs and objectives of the project, the specific implementation scenarios as well as the challenges that may be faced.

As for the system requirements of the TANGENT platform, a total of 154 requirements were successfully collected, which are fundamental to guide the developments to be carried out in the coming months in work packages 2, 3, 4, 5 and 6.

7 References

Autorité Organisatrice de la Mobilité (AOM) in French, as defined by the 2014 MAPTAM Law (LOI n° 2014-58 du 27 janvier 2014 de modernisation de l'action publique territoriale et d'affirmation des métropoles)

LOI n° 2010-1563 du 16 décembre 2010 de réforme des collectivités territoriales

LOI n° 2014-58 du 27 janvier 2014 de modernisation de l'action publique territoriale et d'affirmation des métropoles

Plan de déplacements urbains 2019-2030, https://metropole.rennes.fr/le-plan-de-deplacements-urbains-pdu-2019-2030

Annex I Participation in workshops and questionnaires

The table below identifies the common structure of the workshops held in Lisbon, Rennes, and Manchester. The functionalities covered in each workshop varied based on the choices made by case studies to test certain functionalities. In some of the workshops, questions regarding Service 3 did not take place due to time constraints. These questions were covered in the post-workshop questionnaires.

Topic	Partner responsible/ Moderation
Welcoming participants	
Introduction to workshop, agenda & rules of the webinar	Rupprecht Consult
Case study presentation	Case Study Representative
Presentation of Service 1 functionalities chosen by the case study to be implemented	DEUSTO
Interactive time regarding Service 1 (questions + discussions)	Rupprecht Consult
Break	
Presentation of Service 2 functionalities chosen by the case study to be implemented	DEUSTO
Interactive time regarding service 2 (questions + discussions)	Rupprecht Consult
Presentation of Service 3 functionalities chosen by the case study to be implemented	DEUSTO
Interactive time regarding Service 3 (questions + discussions)	Rupprecht Consult
Conclusion & next steps	Rupprecht Consult

Table 31: Workshop Agenda.

Cities	Total number of participants		
	Pre-workshop questionnaire	Workshop	Post-workshop questionnaire
Lisbon	5	6	4
Manchester	7	7	5
Rennes	3	7	2

Table 32: Participation in the pre-workshop questionnaire, workshops, and post-workshop questionnaire.

Functionalities	Total questions to define service requirements	Questions asked during workshops	Questions asked in the post-workshop questionnaire
S1 - Current state of the TN	29	13	16
S1 - Future state of the TN	14	8	6
S2 - CIM – Sync on-demand and PT	9	7	2
S2 - CIM - Sync traffic control and PT	12	9	3
S2 - NLB – Adaptive traffic control and CAVS	5	5	0
S2 - NLB – Dynamic Congestion Pricing	6	0	0
S2 - NLB – Informing the transport passengers	6	6	0
S3 - COP generation support tool	19	18	1
S3 - Response plan generation support tool	6	5	1
S3 - Simulation of predefined scenarios	8	6	2

Table 33: Distribution of the service requirements questions between the workshops and post-workshop questionnaire.

ANNEX II Final list of system requirements

TANGENT Service	TANGENT Subservice	TANGENT Functionality	System Requirement	System Requirement Type	Priority: Essential, Desirable, Optional	System Requirement Reference
Common to all services			The system shall be customizable with user profiles according to their role.	Functional	Desirable	SR_GEN_001
			The system shall use a login/logout procedure to connect and disconnect the user from TANGENT services	Non-functional	Desirable	SR_GEN_002
			The system shall discard obsolete data	Non-functional	Desirable	SR_GEN_003
			The system shall gather data from different inputs / sources	Functional	Desirable	SR_GEN_004
			The system shall provide interactive maps and map interfaces to the User	Functional	Desirable	SR_GEN_005
			The system shall provide a map environment that provides all road details required	Functional	Desirable	SR_GEN_006
			The system shall use updated map databases (basic road network should be updated at least 4 times a year)	Functional	Desirable	SR_GEN_007
			The system shall provide a user-friendly and up-to-date base map to the User	Functional	Desirable	SR_GEN_008
			The system shall control access to all functionalities according to customizable user profiles across the Dashboard and API	Non-functional	Essential	SR_GEN_009
			The system shall be accessible only using secure communication channels	Non-functional	Essential	SR_GEN_010

TANGENT Service	TANGENT Subservice	TANGENT Functionality	System Requirement	System Requirement Type	Priority: Essential, Desirable, Optional	System Requirement Reference
			The system shall include cybersecurity protection mechanisms namely to avoid DoS and brute force attacks	Non-functional	Essential	SR_GEN_011
			The dashboard and messaging integrations (automatic emails, etc.) must be multi-language and configured for English, French, Portuguese and Greek	Non-functional	Desirable	SR_GEN_012
			Features like chat and messaging must support any character set used (e.g. Greek)	Non-functional	Desirable	SR_GEN_013
Service 1 - Dashboard	-	Current State	The system shall allow the dashboard information for a first time use to be defined by the developers and it should be fully customizable by each user	Functional	Essential	SR_DASH_CS_001
			The system shall allow visualization for dashboard's geolocated information to be switchable between symbolic maps with street names and satellite images with road and buildings visible from above	Functional	Essential	SR_DASH_CS_002
			It should be possible to combine different data elements in the same view.	Functional	Desirable	SR_DASH_CS_003
			The system shall allow visualization of current state of the traffic to be Color-coded using predefined Level of Service values at a road segment level (like Google Maps, Waze, etc.) that could be adjusted on each use case	Functional	Essential	SR_DASH_CS_004
			The system shall allow visualization of current status of the network on strategic roads and main urban arterials	Functional	Essential	SR_DASH_CS_005

TANGENT Service	TANGENT Subservice	TANGENT Functionality	System Requirement	System Requirement Type	Priority: Essential, Desirable, Optional	System Requirement Reference
			The system shall allow to monitor the average delay and occupancy of public transport at line level	Functional	Desirable	SR_DASH_CS_006
			The system shall allow to monitor the global average delay and occupancy of public transport	Functional	Desirable	SR_DASH_CS_007
			The system shall allow for monitoring the public transport system for Bus	Functional	Essential	SR_DASH_CS_008
			The system shall allow for monitoring the public transport system for Metro	Functional	Desirable	SR_DASH_CS_009
			The system shall allow for monitoring the public transport system for Tram	Functional	Desirable	SR_DASH_CS_010
			The system shall show on the dashboard traffic congestions (unspecified origin, due to road block, accident, protest or other) in a part of the network, including duration and location	Functional	Essential	SR_DASH_CS_011
			The system shall provide aggregation timing for traffic and PT data of less than 10 minutes	Functional	Essential	SR_DASH_CS_012
			The system shall provide the aggregation level for traffic and PT data of 500m	Functional	Essential	SR_DASH_CS_013
			The system shall auto-update the dashboard with the current state of traffic with no more than 5 min gap	Functional	Essential	SR_DASH_CS_014
			The system shall manage a registration procedure to guarantee public access to the external API	Functional	Essential	SR_DASH_CS_015
			The system shall expose traffic status to external users through the API	Functional	Essential	SR_DASH_CS_016

TANGENT Service	TANGENT Subservice	TANGENT Functionality	System Requirement	System Requirement Type	Priority: Essential, Desirable, Optional	System Requirement Reference
		Future State	The system shall predict traffic status for strategic roads	Functional	Essential	SR_DASH_FS_001
			The system shall predict traffic status in main urban arterial roads	Functional	Essential	SR_DASH_FS_002
			The system shall predict traffic status in interurban areas	Functional	Desirable	SR_DASH_FS_003
			The system shall predict traffic status in all urban roads	Functional	Desirable	SR_DASH_FS_004
			The system shall predict the future congestion at road segment level	Functional	Essential	SR_DASH_FS_005
			The system shall predict the future average delay for relevant and predefined routes	Functional	Desirable	SR_DASH_FS_006
			The system shall provide future traffic predictions for 5 min	Functional	Essential	SR_DASH_FS_007
			The system shall provide future traffic predictions for 15 min	Functional	Essential	SR_DASH_FS_008
			The system shall provide future traffic predictions for 60 min	Functional	Desirable	SR_DASH_FS_009
			The system shall provide future traffic predictions up to 24 h	Functional	Optional	SR_DASH_FS_010
			The system shall consider an update frequency of the traffic predictions of less than 15 min	Functional	Essential	SR_DASH_FS_011
			The system shall consider an update frequency of the traffic predictions of less than 15 min	Functional	Desirable	SR_DASH_FS_012

TANGENT Service	TANGENT Subservice	TANGENT Functionality	System Requirement	System Requirement Type	Priority: Essential, Desirable, Optional	System Requirement Reference
			The system shall consider predicting future state of public transport system for Bus	Functional	Essential	SR_DASH_FS_013
			The system shall consider predicting future state of the public transport system for Metro	Functional	Optional	SR_DASH_FS_014
			The system shall consider predicting future state of the public transport system for Tram	Functional	Optional	SR_DASH_FS_015
			The system shall predict the average delay of public transport at line level	Functional	Essential	SR_DASH_FS_016
			The system shall predict the average occupancy of public transport at line level	Functional	Optional	SR_DASH_FS_017
			The system shall predict the global average delay of public transport	Functional	Optional	SR_DASH_FS_018
			The system shall predict the global average occupancy of public transport	Functional	Optional	SR_DASH_FS_019
			The system shall predict the delay of public transport at individual vehicle level	Functional	Optional	SR_DASH_FS_020
Service 2 - RT Traffic Management	CIM	Sync traffic control and PT	The system and the operators shall synchronize traffic control with the schedule of bus public transport in a specific corridor	Functional	Essential	SR_CIM_TCPT_001
			The system and the operators shall synchronize traffic control with the frequency of bus public transport in a specific corridor	Functional	Desirable	SR_CIM_TCPT_002
			The system and the operators shall synchronize traffic control with the schedule of bus public transport in a specific area	Functional	Desirable	SR_CIM_TCPT_003

TANGENT Service	TANGENT Subservice	TANGENT Functionality	System Requirement	System Requirement Type	Priority: Essential, Desirable, Optional	System Requirement Reference
			The system and the operators shall synchronize traffic control with the frequency of bus public transport in a specific area	Functional	Desirable	SR_CIM_TCPT_004
			The system shall provide this service to authorities, public transport operators and infrastructure providers	Non-functional	Essential	SR_CIM_TCPT_005
			The system and the operators shall optimize the public transport system performance in average travel times	Functional	Essential	SR_CIM_TCPT_006
			The system and the operators shall optimize the public transport system performance in delays	Functional	Essential	SR_CIM_TCPT_007
			The system and the operators shall optimize the public transport system performance in waiting times	Functional	Desirable	SR_CIM_TCPT_008
			The system and the operators shall define how to synchronize the public transport operations and traffic control during the CIM planning phase for planned events	Functional	Essential	SR_CIM_TCPT_009
			The system and the operators shall define how to synchronize the public transport operations and traffic control during the CIM planning phase for unplanned events	Functional	Essential	SR_CIM_TCPT_010
		Sync On-Demand and PT	The system and the operators shall synchronize on-demand transport with the metro	Functional	Desirable	SR_CIM_ODPT_001
			The system and the operators shall synchronize on-demand transport with the rail	Functional	Desirable	SR_CIM_ODPT_002

TANGENT Service	TANGENT Subservice	TANGENT Functionality	System Requirement	System Requirement Type	Priority: Essential, Desirable, Optional	System Requirement Reference
			The system and the operators shall synchronize on-demand transport with the bus	Functional	Desirable	SR_CIM_ODPT_003
			The system and the operators shall synchronize on-demand transport with the tram	Functional	Desirable	SR_CIM_ODPT_004
			The system and the operators shall synchronize on-demand transport at Peri-urban area	Functional	Desirable	SR_CIM_ODPT_005
			The system and the operators shall synchronize on-demand transport at Metropolitan area	Functional	Desirable	SR_CIM_ODPT_006
			The system and the operators shall synchronize on-demand transport at rural areas (medium distance from the city)	Functional	Desirable	SR_CIM_ODPT_007
			The system and the operators shall synchronize public transport operations and on-demand transport operations after a planned event. This happens after the COP has already been agreed in the planning phase	Functional	Desirable	SR_CIM_ODPT_008
			The system and the operators shall synchronize public transport operations after a planned event. This happens after the COP has already been agreed in the planning phase.	Functional	Desirable	SR_CIM_ODPT_009
			The system and the operators shall synchronize public transport operations after an unplanned event after the COP has already been agreed in the planning phase. On-demand transport should be optimized in real-time	Functional	Desirable	SR_CIM_ODPT_010

TANGENT Service	TANGENT Subservice	TANGENT Functionality	System Requirement	System Requirement Type	Priority: Essential, Desirable, Optional	System Requirement Reference
			The system and the operators shall update public transport operations and on-demand transport operations in real-time after an unplanned event	Functional	Desirable	SR_CIM_ODPT_011
			The system and the operators shall optimize the synchronization of DRT and public transport according to the Public transport system performance (average travel times, delays, waiting times, etc.)	Functional	Desirable	SR_CIM_ODPT_012
			The system and the operators shall optimize the synchronization of DRT and public transport according to Operational costs	Functional	Desirable	SR_CIM_ODPT_013
			The system and the operators shall optimize the synchronization of DRT and public transport according to the number of passengers served	Functional	Desirable	SR_CIM_ODPT_014
	NLB	Informing Transport Passengers	The system shall provide this service to: public transport operators, Content service providers, In-car service providers, Roadside service providers, Service consumers, Authorities	Non-functional	Essential	SR_NLB_ITP_001
			The system shall inform about traffic congestion to the different actors	Functional	Essential	SR_NLB_ITP_002
			The system shall inform about traffic accidents and breakdowns/blockages to the different actors	Functional	Essential	SR_NLB_ITP_003
			The system shall inform about road obstacles (e.g. protests, mobs, fallen trees, fallen cargo, etc.) to the different actors	Functional	Desirable	SR_NLB_ITP_004

TANGENT Service	TANGENT Subservice	TANGENT Functionality	System Requirement	System Requirement Type	Priority: Essential, Desirable, Optional	System Requirement Reference
			The system shall inform about adverse weather conditions to the different actors	Functional	Optional	SR_NLB_ITP_005
			The system shall suggest traffic authorities to use Road Variable Message Signs, providing the corresponding message format	Functional	Optional	SR_NLB_ITP_006
			The system shall inform traffic authorities to expose the processed traffic information using their social networks or applications from content service providers (Waze, Google Maps, etc.)	Functional	Optional	SR_NLB_ITP_007
			The system shall inform about public transport excessive delays to the different actors	Functional	Desirable	SR_NLB_ITP_008
			The system shall inform about public transport incidents (e.g. vehicle breakdown, accidents, etc) to the different actors	Functional	Desirable	SR_NLB_ITP_009
			The system shall provide relevant information to public transport operators at the Line level	Functional	Desirable	SR_NLB_ITP_010
			The system shall provide relevant information to public transport operators at the Station level	Functional	Desirable	SR_NLB_ITP_011
			The system shall provide relevant information to public transport operators at the Section level	Functional	Desirable	SR_NLB_ITP_012
			The system shall provide relevant information to public transport operators at the Area level	Functional	Optional	SR_NLB_ITP_013
			The system shall inform all actors about the Type of situation	Functional	Essential	SR_NLB_ITP_014

TANGENT Service	TANGENT Subservice	TANGENT Functionality	System Requirement	System Requirement Type	Priority: Essential, Desirable, Optional	System Requirement Reference
			The system shall inform all actors about the Planned resolution date / time when that information is available or it can be estimated	Functional	Essential	SR_NLB_ITP_015
			The system shall inform all actors about the Suggested actions	Functional	Desirable	SR_NLB_ITP_016
			The system shall inform all actors about the Severity	Functional	Desirable	SR_NLB_ITP_017
			The system shall inform all actors about the Area Affected	Functional	Optional	SR_NLB_ITP_018
		Dynamic Congestion Pricing	The system shall provide DCP to: Infrastructure providers, Service consumers, Authorities	Functional	Essential	SR_NLB_DCP_001
			The system shall implement a Zone-based DCP (Involves charges to drive within or into a congested area within a city).	Functional	Optional	SR_NLB_DCP_002
			The system shall implement a Distance-based DCP (toll in terms of the distance traveled by drivers, either linearly or nonlinearly)	Functional	Desirable	SR_NLB_DCP_003
			The system shall implement a Congestion-based DCP (toll in terms of the total time delay incurred by drivers, either linearly or nonlinearly)	Functional	Optional	SR_NLB_DCP_004
			The system shall consider traffic system performance (average travel times, traffic delays, etc.) when deciding what dynamic response pricing scheme to apply as a response plan	Functional	Desirable	SR_NLB_DCP_005
			The system shall consider public transport system performance (average travel times, delays, waiting	Functional	Optional	SR_NLB_DCP_006

TANGENT Service	TANGENT Subservice	TANGENT Functionality	System Requirement	System Requirement Type	Priority: Essential, Desirable, Optional	System Requirement Reference
			times, etc.) when deciding what dynamic response pricing scheme to apply as a response plan			
			The system shall consider Environmental impact (CO2, NOX, … emissions, etc.) when deciding what dynamic response pricing scheme to apply as a response plan	Functional	Essential	SR_NLB_DCP_007
			The system shall consider Operational costs when deciding what dynamic response pricing scheme to apply as a response plan	Functional	Essential	SR_NLB_DCP_008
		Adaptive traffic Control and CAVs	The system shall consider traffic system performance (average travel times, traffic delays, etc.) when deciding the optimal response plan to apply using adaptive traffic control and CAVs	Functional	Desirable	SR_NLB_ATCAV_001
			The system shall consider Operational costs when deciding the optimal response plan to apply using adaptive traffic control and CAVs	Functional	Desirable	SR_NLB_ATCAV_002
			The system shall consider Signal timings and cycles at specific corridor/s for the generation of the response plans associated with the adaptive traffic control and CAVs	Functional	Desirable	SR_NLB_ATCAV_003
			The system shall consider the parametrization of SCOOT/other optimization algorithms at specific corridors for the generation of the response plans associated with the adaptive traffic control and CAVs	Functional	Desirable	SR_NLB_ATCAV_004
			The system shall consider using Variable Message Signs to propose alternative routes to all drivers for	Functional	Desirable	SR_NLB_ATCAV_005

TANGENT Service	TANGENT Subservice	TANGENT Functionality	System Requirement	System Requirement Type	Priority: Essential, Desirable, Optional	System Requirement Reference
			the generation of the response plans associated with the adaptive traffic control and CAVs			
			The system shall consider Sending rerouting instructions or guidance for Connected Vehicles for the generation of the response plans associated with the adaptive traffic control and CAVs	Functional	Desirable	SR_NLB_ATCAV_006
			The system shall consider Sending rerouting instructions or guidance for Autonomous Vehicles for the generation of the response plans associated with the adaptive traffic control and CAVs	Functional	Desirable	SR_NLB_ATCAV_007
			The system shall consider Fleet allocation (meaning - routes and schedules) for CAV fleets for the generation of the response plans associated with the adaptive traffic control and CAVs	Functional	Desirable	SR_NLB_ATCAV_008
			The system shall consider the size of CAV fleets for the generation of the response plans associated with the adaptive traffic control and CAVs	Functional	Desirable	SR_NLB_ATCAV_009
Service 3 – Transport network optimization for Transport Authorities	-	Common Operational Picture generation support tool	The system shall provide this service to: public transport operators, infrastructure providers, Roadside service providers and Authorities	Non-functional	Essential	SR_TNO_COP_001
			The system shall support the creation of a view with different map elements that will be called the COP	Functional	Essential	SR_TNO_COP_002
			The system shall provide actors with a tool to collaboratively define the different scenarios of the COP	Functional	Essential	SR_TNO_COP_003

TANGENT Service	TANGENT Subservice	TANGENT Functionality	System Requirement	System Requirement Type	Priority: Essential, Desirable, Optional	System Requirement Reference
			The system shall provide actors with a tool to collaboratively define the triggering conditions of the Scenarios of the COP	Functional	Essential	SR_TNO_COP_004
			The system shall provide actors with a tool to collaboratively and manually define the response plans of the COP according to the scenarios and triggering conditions	Functional	Essential	SR_TNO_COP_005
			The system shall define a minimum LoS establishing a threshold on the mode of transport: road, bus, metro, etc...	Functional	Essential	SR_TNO_COP_006
			The system shall define a minimum LoS establishing a threshold on the transport network element: road section, public transport line, etc.	Functional	Optional	SR_TNO_COP_007
			The system shall support the manual definition of the triggering conditions for the mode of transport (road transport, bus, metro, etc.)	Functional	Essential	SR_TNO_COP_008
			The system shall support the manual definition of the triggering conditions for each transport network element (road section, public transport line, etc.)	Functional	Essential	SR_TNO_COP_009
			The system shall support the manual definition of the triggering conditions for different KPI indicators (e.g. delay > 10 mins, failure in PT line, average speed < 50% of free-flow speed, etc.)	Functional	Essential	SR_TNO_COP_010
			The system shall support the automatic definition of the triggering conditions for different KPI indicators (e.g. delay > 10 mins, failure in PT line, average speed < 50% of free-flow speed, etc.)	Functional	Optional	SR_TNO_COP_011

TANGENT Service	TANGENT Subservice	TANGENT Functionality	System Requirement	System Requirement Type	Priority: Essential, Desirable, Optional	System Requirement Reference
			The system shall provide actors with an automatically optimized response plan for the Synchronization of Public Transport and Traffic Control	Functional	Essential	SR_TNO_COP_012
			The system shall provide actors with an automatically optimized response plan for the Synchronization of DRT and Transit Modes	Functional	Optional	SR_TNO_COP_013
			The system shall provide actors with an automatically optimized response plan for Dynamic Congestion Pricing	Functional	Essential	SR_TNO_COP_014
			The system shall provide actors with an automatically optimized response plan for Adaptive Traffic Control and CAVs	Functional	Desirable	SR_TNO_COP_015
			The system shall provide actors with an automatically optimized response plan (from those four available) for a particular planned or unplanned event in 5 hours	Functional	Optional	SR_TNO_COP_016
			The system shall provide actors with an automatically optimized response plan (from those four available) for a particular planned or unplanned event in 7 hours	Functional	Desirable	SR_TNO_COP_017
			The system shall provide actors with an automatically optimized response plan (from those four available) for a particular planned or unplanned event in 24 hours	Functional	Essential	SR_TNO_COP_018

TANGENT Service	TANGENT Subservice	TANGENT Functionality	System Requirement	System Requirement Type	Priority: Essential, Desirable, Optional	System Requirement Reference
			The system shall provide actors with an automatic response plan optimizing Public transport performance (average travel time, waiting time)	Functional	Essential	SR_TNO_COP_019
			The system shall provide actors with an automatic response plan optimizing traffic system performance (average travel time, waiting time)	Functional	Essential	SR_TNO_COP_020
			The system shall provide actors with an automatic response plan optimizing road safety	Functional	Optional	SR_TNO_COP_021
			The system shall provide actors with an automatic response plan optimizing citizen acceptance (reliability, inclusion, accessibility, equity, comfort)	Functional	Optional	SR_TNO_COP_022
			The system shall take into account the different governance models of each use case in the decision making tool and support different priorities for actors	Functional	Essential	SR_TNO_COP_023
			The system shall exchange relevant data among different actors to facilitate the generation of the COP	Functional	Essential	SR_TNO_COP_024
			The system shall provide a direct communication tool among actors to facilitate cooperation and agreements for the generation of the COP	Functional	Essential	SR_TNO_COP_025
		Response plan generation tool	The system shall provide actors with an automatically optimized response plan for the Synchronization of Public Transport and Traffic Control	Functional	Essential	SR_TNO_RPGT_001

TANGENT Service	TANGENT Subservice	TANGENT Functionality	System Requirement	System Requirement Type	Priority: Essential, Desirable, Optional	System Requirement Reference
			The system shall provide actors with an automatically optimized response plan for the Synchronization of DRT and Transit Modes	Functional	Optional	SR_TNO_RPGT_002
			The system shall provide actors with an automatically optimized response plan for Dynamic Congestion Pricing	Functional	Essential	SR_TNO_RPGT_003
			The system shall provide actors with an automatically optimized response plan for Adaptive Traffic Control and CAVs	Functional	Desirable	SR_TNO_RPGT_004
			The system shall support the generation of a response plan for planned events that can lead to disruptions of elements of the transport network (football games, expositions, concerts etc.)	Functional	Desirable	SR_TNO_RPGT_005
			The system shall support the generation of a response plan for unplanned events that can lead to disruptions of elements of the transport network (e.g. weather events, traffic incidents, wildfires, etc.)	Functional	Desirable	SR_TNO_RPGT_006
			The system shall optimize the traffic system performance (average travel times, traffic delays, etc.) when producing a response plan	Functional	Desirable	SR_TNO_RPGT_007
			The system shall optimize the public transport system performance (average travel times, delays, waiting times, etc.) when producing a response plan	Functional	Desirable	SR_TNO_RPGT_008
			The system shall optimize the operational costs when producing a response plan	Functional	Optional	SR_TNO_RPGT_009

TANGENT Service	TANGENT Subservice	TANGENT Functionality	System Requirement	System Requirement Type	Priority: Essential, Desirable, Optional	System Requirement Reference
		Simulation of pre-defined scenarios	The system shall complete a simulation in 2 hours	Functional	Optional	SR_TNO_SPS_001
			The system shall complete a simulation in 5 hours	Functional	Desirable	SR_TNO_SPS_002
			The system shall complete a simulation in 7 hours	Functional	Essential	SR_TNO_SPS_003
			The system shall provide the traffic system performance (average travel times, traffic delays, etc.) as an output of the simulation	Functional	Essential	SR_TNO_SPS_004
			The system shall provide the public transport system performance (average travel times, delays, waiting times, etc.) as an output of the simulation	Functional	Essential	SR_TNO_SPS_005
			The system shall provide the environmental impact (CO2, NOX, … emissions, etc.) as an output of the simulation	Functional	Desirable	SR_TNO_SPS_006
			The system shall provide the impact on active modes as an output of the simulation	Functional	Optional	SR_TNO_SPS_007
			The system shall provide the operational costs as an output of the simulation	Functional	Optional	SR_TNO_SPS_008
			The system shall provide a road safety indicator as an output of the simulation	Functional	Optional	SR_TNO_SPS_009
			The system shall provide the citizen acceptance (reliability, inclusion, accessibility, equity, comfort) as an output of the simulation	Functional	Optional	SR_TNO_SPS_010

Table 34: List of the System Requirements for the project TANGENT.