TANGENT

Assessment of the testing results in the Case Study of Greater Manchester

D7.5

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Executive summary

Greater Manchester (GM) is a large city region in the North West of England with 2.73 million residents across 1,276 square kilometres. GM is the UK's first combined authority (GMCA), bringing together 10 local authorities to address strategic challenges. With over 2.1 billion journeys annually, including 268 million by public transport, GM faces issues such as congestion, air quality, and heavy reliance on private vehicles. Transport for Greater Manchester (TfGM) plays a central role in managing the city's multimodal transport network and is delivering the transition to the Bee Network, an integrated transport system.

As a case study in the TANGENT project, Greater Manchester focused on improving the management of its multi-modal transport system. Three TANGENT services were tested. Service 1, an enhanced multimodal information service, consolidated real-time data (e.g., from Waze, buses) into a unified dashboard to improve network visibility. Service 2 focused on synchronising public transport and traffic control systems, offering potential benefits for incident management, particularly in anticipation of the Bus Franchising model being fully implemented by 2025. Service 3 tested the simulation of scenarios like increasing bus frequency and optimising the network for connected vehicles, aligning with TfGM's vision for future transport strategies.

The testing of TANGENT's tools helped TfGM assess the benefits of data sharing and multimodal coordination. The case study targeted key transport corridors and events (e.g., football matches and concerts), enabling TfGM to better manage the impacts on the network. The project also reinforced the importance of high-quality, real-time data and a collaborative approach to traffic management.

Moving forward, TfGM sees the potential to integrate TANGENT's tools into their existing systems, contributing to a future operational strategy that enhances predictive capabilities and multimodal traffic management across Greater Manchester.

The remainder of this deliverable will provide a detailed overview of the methodology employed during the testing activities within the TfGM case study. It will present the results of these tests, focusing on the use of TANGENT's tools in a live operational environment, and highlight specific challenges encountered, such as data integration. Additionally, the deliverable will explore the lessons learned from the project, particularly in relation to multi-actor collaboration, the availability of data, and the benefits of simulating transport scenarios. Finally, it will outline TfGM's next steps, including how these findings will inform the future development of traffic management systems and operational strategies in Greater Manchester.

Key words

Multimodal, Data integration, Traffic management, Simulation, Collaboration, Operational strategies, Future development

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List of abbreviations and acronyms

Acronym	Meaning
AMQP	Advanced Message Queuing Protocol
CIM	Cooperative Incident Management
CS	Case Study
CSV	Comma-Separated Values
DRT	Demand Responsive Transport
DTA	Dynamic Traffic Assignment
EC	European Commission
GA	Grant Agreement
HTML	HyperText Markup Language
KCONG	Knowledge Catalog and Governance
KPI	Key Performance Indicator
KRN	Key Route Network
LoS	Level of Service
NAP	National Access Point
OP	Other Partners
R&D	Research & Development
RDF	Resource Description Framework
SCS	Stakeholder Cooperation Survey
SNLB	Smart Network Load Balance
TBS	Travel Behavior Survey
TC	Traffic Control
TfGM	Transport for Greater Manchester

TMB	TANGENT Data Catalogue Management Board
TMS	Traffic Management System
WP	Work Package

1 Introduction

1.1 Attainment of the objectives and explanation of deviations

The main objective of this deliverable is to present the results of TANGENT for the Greater Manchester (TfGM) case study. In line with WP7 "FUTURE TRANSPORT CASE STUDIES," this document primarily addresses the outcomes of T7.2 "Operation of the tests: testing of subsystems" and T7.3 "Upscaling and full operation: testing of the overall system," comparing them with the initial expectations set by the TfGM case study during T7.1 "Definition of Case Studies, stakeholders' engagement and tests preparation," as documented in D7.1 "Definition of the Case Studies, testing methodology and stakeholders' & users' engagement campaign" and D7.2 "System deployment and testing specifications." These documents outlined the TfGM case study, including its requirements, testing environment, and the scenarios under which the tests would be conducted.

Specifically, this deliverable presents the results of the tests performed with the TfGM case study for the three key services of TANGENT, assessed under baseline, planned, and unplanned event scenarios. The scenarios selected included events such as football matches at Old Trafford and concerts at the AO Arena. These scenarios represent real-life challenges for multimodal transport management.

As detailed in this deliverable, some testing is still ongoing due to a higher-than-expected technical complexity in one of the modules related to data integration. The testing activity will continue until the project's conclusion to ensure the full evaluation of all systems.

1.2 Intended audience

This deliverable is public. First, it can be retained, reused, and disseminated by Transport for Greater Manchester (TfGM) to exploit the results of the TANGENT project. It can also be consulted by local stakeholders involved in the project's workshops, demonstrations, and tests, even if they are not part of the consortium. More broadly, this deliverable can be accessed by any interested party, including stakeholders involved in traffic and transport management, technology providers, other metropolitan areas or transport operators, researchers, or those engaged in other R&D projects.

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

This deliverable is structured into four key sections:

- The first section, *"Testing of the Subsystems"*, presents the results of the individual subsystem tests. Prior to the development of a consolidated platform, technical partners developed and tested subsystems with TfGM to assess accuracy. This section outlines the methodology and results for each tested subsystem.
- The second section provides a brief presentation of the TfGM case study, allowing the reader to understand the context of the TANGENT project and the specific tests applied to Greater Manchester.

- The third section, *"Testing of the Overall System"*, discusses the tests conducted on the integrated system, which combines the developed subsystems into a single tool. It includes the testing methodology and results for each functionality within a variety of scenarios in Greater Manchester.
- The fourth and final section covers the lessons learned from the TfGM case study, particularly after testing the subsystems and tools, and outlines the next steps for TfGM after the project concludes.

The deliverable D7.5 is linked to other work packages and deliverables:

- Within WP7, this document relates to D7.1 *"Definition of the Case Studies, Testing Methodology, and Stakeholders' & Users' Engagement Campaign"* and D7.2 *"System Deployment and Testing Specifications"*, which outlined the case study and its requirements. It is also linked to D7.3, D7.4, and D7.6, as some methodologies and testing activities were shared across case studies. Additionally, D7.7 provides an impact assessment, including the analysis of TfGM's project KPIs.
- This document is linked to WP1 workshops, particularly the Stage 3 stakeholders' workshop in Greater Manchester, where a demonstration of the tool took place, and local stakeholders provided feedback.
- D7.5 is closely connected to WP6, specifically D6.5 *"TANGENT Tool Development and Integration. Second Release"*, which describes the overall tool, dashboard functionalities, and technical testing. This document is referenced in several sections of D7.5.

2 Presentation of the Greater Manchester case study

Greater Manchester (GM) is a large city region in the North West of England with 2.73 million residents across 1,276 square kilometres. GM is the UK's first combined authority (GMCA), representing 10 local authorities working together on strategic challenges. Over 2.1 billion journeys occur annually, including 268 million by public transport. Heavy reliance on private vehicles, even for short trips, causes urban congestion and worsens air quality, costing GM businesses £1.3 billion.

TfGM operates the tram system, subsidises local rail, maintains bus shelters, and funds certain fares and station improvements. It also runs Metro Shuttle services and is developing smart ticketing apps. Following the Bus Services Act (2017), TfGM is bringing buses under local control to create the integrated Bee Network, improving service planning and allowing easier, affordable transport across modes. This process will be complete by January 2025.

Manchester's key challenges include managing congestion and integrating buses, trams, trains, and active travel to encourage a shift to sustainable modes. The city will test project services in parts of the Regional Centre and strategic corridors to better manage the transport network. The baseline scenario focuses on a typical day on the western side of the Regional Centre and parts of the Key Route Network.

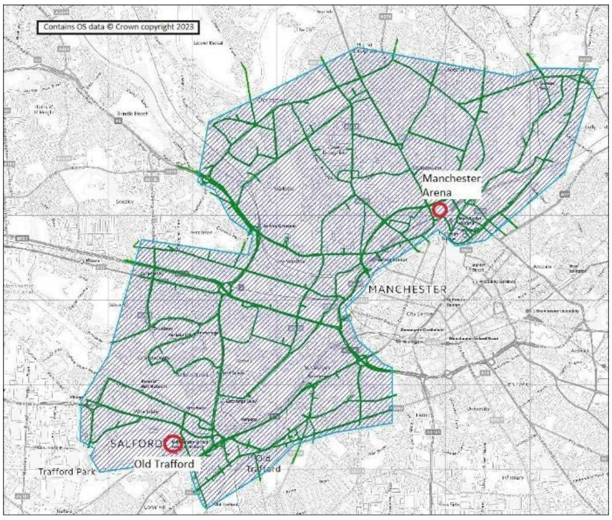

Figure 1: Case study area

2.1 Planned Events

Football Match - Manchester United (Old Trafford) Home Match: This was chosen due to its frequent occurrence and significant impact on Greater Manchester's transport network, particularly during evening kick-offs, which cause the most disruption. These matches affect multiple transport modes, especially in the Regional Centre (part of the area covered by existing/planned modelling for the TANGENT project). In 2022, the average home attendance at Old Trafford was 73,690—the highest in world football.

Concert - Manchester Arena (AO Arena): Concerts at the AO Arena are selected for their frequent impact on the transport network. Like football matches, evening events put extra pressure on transport modes, particularly during the PM peak. The AO Arena is located on the Regional Centre Ring Road, an area included in the modelling for the TANGENT project. The venue has a capacity of 21,000 and attracts over 1 million attendees annually.

2.2 Unplanned Events

Road traffic collisions and incidents causing delay and lane closure: Selected due to frequent impact on the network, requiring TfGM intervention. Collisions and lane closures primarily affect highways but also disrupt the bus and Metrolink systems. Focus will be on major routes into the Regional Centre (e.g., A56 Chester Rd, A57 Regent Rd).

Major incidents causing delay and traffic diversions: Similar to collisions but specifically targeting incidents that result in traffic diversions.

Unplanned/emergency roadworks: Chosen due to their significant impact across various transport modes and the need for TfGM intervention. Focus will be on major routes providing access to the Regional Centre.

2.3 Perimeter delimitation for tests

TfGM identified the study area (Figure 2) in consultation with the internal modelling team, based on available data and models. It covers the western side of Greater Manchester Regional Centre and key routes (KRN), capturing major transport modes for the selected events and scenarios, as well as high traffic volumes. The area is heavily impacted by these events, making it ideal for simulation.

The mesoscopic model (Figure 2) was developed in Aimsun by TfGM's team. This level of modelling allows for better validation before testing. An evening peak model assessed the impacts of planned events (football match and arena event) alongside commuter traffic, focusing on strategic bus services like X50, 255, 250, V1, and others.

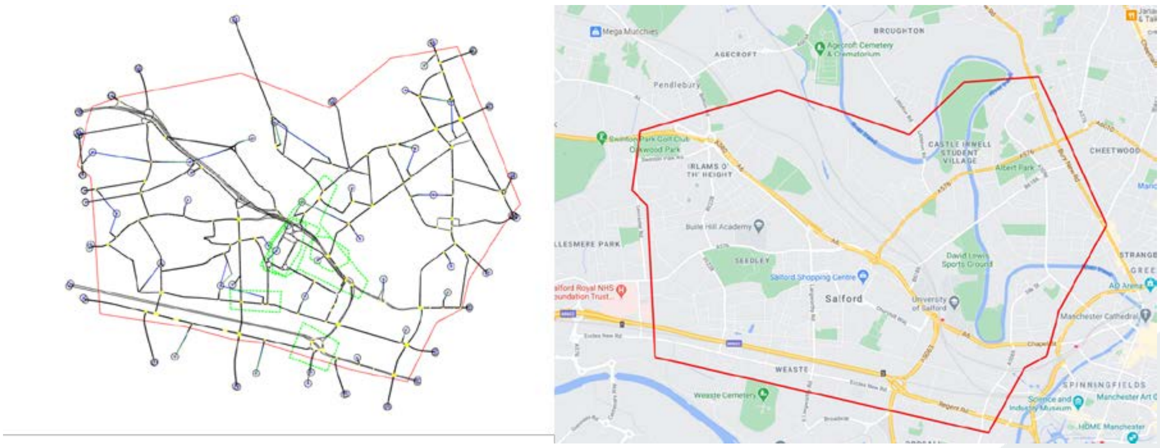

Figure 2: Modelled areas

2.4 Transport modes and infrastructures involved

TfGM operates a strategic network of Automatic Traffic Counters (ATCs) that provide 'real-time' (within 5 minutes) traffic flow, speed and vehicle classification data on the Highway (shown on map in Figure 3). In addition to this, TfGM maintains a network of Bluetooth journey time sensors that can be used to monitor vehicle travel times across key corridors on the network. This is further enhanced by the data available through the WAZE connected cities API, which also provides real-time journey time data across the highway network. This data is available within the proposed study area. Also shown within the study in Figure 3 is the location of the traffic signals that are operating on the Highway Network, alongside TfGM operated CCTV sites and Variable Message Signs (VMS). There is a separate map that has been provided (to the consortium) which indicates the mode of operation of each set of traffic signals and another, which outlines the different types of traffic signal control within the study area (dynamic, fixed, and actuated)

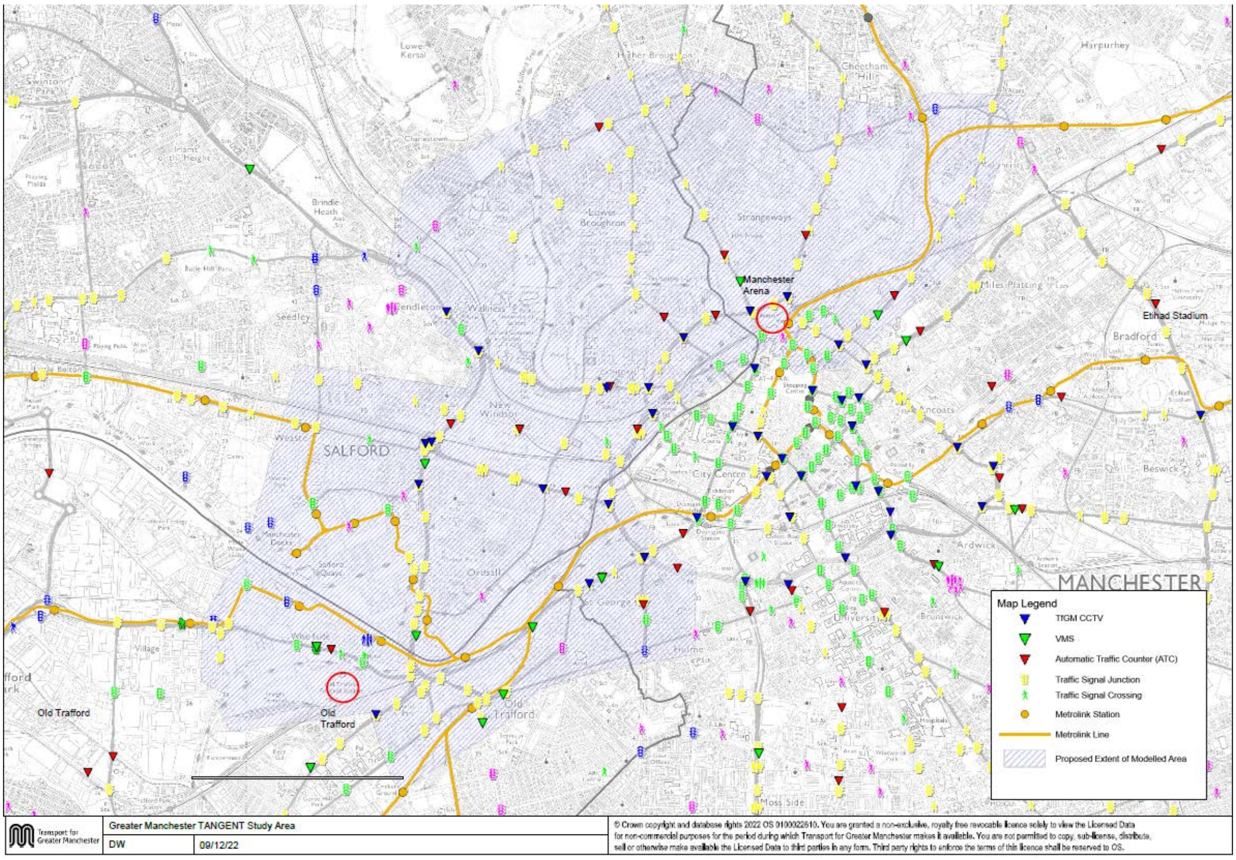

Figure 3: Transport modes included within the proposed modelled study area are private vehicles and PT (bus services and Metrolink - Tram)

Within the modelled area outlined in Figure 3 are a number of strategic routes / corridors that facilitate Regional Centre Ingress/Egress, in addition to serving the planned event scenarios (Old Trafford and AO Arena). These are:

- A57 Regent Road
- A6 Crescent / Chapel St
- A57 (M) Mancunian Way
- A6052 Trinity Way
- A665 Great Ancoats St
- A56 Chester Rd
- A56 Bury New Rd

The Metrolink (Tram) line(s) are also shown in figure 3, with stops also indicated. Individual bus services/routes will be shown separately and included within the transport model. Key bus services included in this are:

X50, 255, 250, 256 V1, V2, 67, 100, 97, 98, 33, 34

Specific detail for these routes will be provided within the transport model (Figure 1), though each route is outlined on the TfGM Webpage (https://tfgm.com/public-transport/bus/routes).

2.5 TANGENT Tools and Services Applied to Greater Manchester

Service 1 - Current Status: TANGENT Service 1 (Enhanced information for multimodal transport) will offer stakeholders a unified view of Greater Manchester's transport network. TfGM's Control Centre staff currently use multiple systems, but this service will consolidate real-time data (e.g., WAZE, Metrolink, bus data) into a single dashboard, improving network visibility and operational efficiency.

Service 1 - Future Status: Along with real-time data, Service 1 will include a predictive tool to visualise future network conditions. TfGM staff will use this to assess the impact of incidents and disruptions across transport modes, enhancing decision-making and stakeholder communication.

Service 2 - CIM: Synchronisation of PT and TC: TANGENT Service 2 will explore the potential benefits of synchronising public transport (PT) and traffic control (TC) systems. This is not currently feasible due to private bus operators, but with Bus Franchising on the horizon, TfGM is interested in testing this functionality to improve response plans for network disruptions.

Service 2 - SNLB: Informing Transport Passengers: Using the multi-modal data from Service 1, this service will assess how rebalancing PT supply (bus and Metrolink) can optimise network performance. Information from the Smart Network Load Balance (SNLB) will be shared with passengers via social media, VMS, and journey planning apps, enhancing TfGM's ability to manage the network effectively.

Service 3 - Simulation of Pre-defined Scenarios: TfGM will test two scenarios using Service 3:

- Increasing bus capacity and frequency on key routes to support modal shift to PT.
- Simulating higher penetration of connected vehicles with V2X communication, assessing impacts on network performance and technologies like Green Light Optimal Speed Advisory (GLOSA). These tests align with TfGM's future transport strategies.

KPIs for the case study are addressed in Deliverable 7.7.

3 Testing of the subsystems

This section describes the testing activities carried out during T7.2 *"Operation of the Tests: Testing of Subsystems"*, in collaboration with the technical partners and the first release of their subsystems. The methodology follows an *"Applied Learning Cycle"*: after the technical partners developed the first release of their subsystems, they organised tests with the case studies, including TfGM, to assess the accuracy of their results. The feedback and results from these testing activities were then used to enhance the second release of their subsystems.

Each technical partner worked on a different type of subsystem, and therefore provided a testing methodology specifically tailored to the component being assessed. The following subsections present the subsystems tested, the methodology applied during testing, and the results of these activities for the TfGM case study.

A significant portion of these elements is common to the deliverables for the other case studies, especially the non-virtual ones, such as D7.4 for Lisbon and D7.3 for Rennes. The decision was made to duplicate these sections across all relevant deliverables, rather than referring to other documents, to ensure consistency. This approach guarantees that each case study has a complete, standalone deliverable, which they can use and disseminate in their local ecosystem after the project's conclusion. For Greater Manchester, this ensures that the document serves as a comprehensive record of the specific activities and learnings relevant to the region.

3.1 Data harmonisation and fusion

The TANGENT Solution for Data Harmonisation and Fusion represent the subsystem developed within WP2 and integrated into the overall TANGENT solution. The first release of the solution is described in D2.3, and the final one, incorporating the feedback received during its testing, is in D2.4. The main components of the TANGENT Solution for Data Harmonisation and Fusion are:

- the *TANGENT Data Catalogue*: a digital platform enabling data-sharing among different stakeholders;
- the *TANGENT Reference Conceptual Model*: defining a reference ontology for the transportation-related data handled within TANGENT;
- the *Semantic Harmonisation and Fusion Pipelines* to fulfil the integration requirements associated with TANGENT data sources;
- the *TANGENT Data API*: a uniform mechanism to access data sources collected and harmonised by WP2.

The testing of the WP2 subsystem mainly focused on the TANGENT Data Catalogue, which provides a user interface designed to be directly accessible by relevant stakeholders. The testing of the other components has been performed (i) with TANGENT partners from a technical perspective to enable the integration of the different subsystems and (ii) indirectly by stakeholders involved in the testing of other subsystems integrated with the WP2 solution.

The TANGENT Data Catalogue is developed using the Knowledge Catalog and Governance (KCONG) framework by Cefriel. KCONG provides a customizable platform for defining and managing digital asset catalogues, accessible online via a web browser. It supports various digital asset types, each characterized by specific metadata descriptors for user interaction. KCONG allows programmatic access to the list of assets and their metadata, which can be serialized in RDF for advanced querying and automated processing. It also enables the configuration of governance processes for digital assets using the BPMN formalism.

For the TANGENT Data Catalogue, a customised KCONG instance includes:

- organisation of digital assets based on TANGENT case studies;
- a Data Source asset type to describe datasets and data services, adhering to the TangentDCAT-AP metadata specification (see D2.2);
- integration of BPMN processes to support TANGENT Data-Sharing Governance rules (see D2.2).

3.1.1 Methodology

The methodology for the TANGENT Data Catalogue considered two distinct types of testing.

The first type involves gathering feedback on the initial version of the TANGENT Data Catalogue. This feedback-driven testing aims to identify areas for improvement to ensure the second and final release of the TANGENT Data Catalogue meets users' requirements. Given that the TANGENT Data Catalogue is a software artefact used uniformly by project partners, the feedback gathered through its testing methodology is not specific to any single use case. Instead, we collected and analysed anonymous data from all participating partners across use cases to obtain a comprehensive assessment of the catalogue's usability and functionality. By analysing this feedback, we identified common issues and areas for improvement that were used to enhance the overall user experience in the final release of the WP2 solution described in D2.4.

The second type of testing focuses on the catalogue's practical usage within the project. This in-project testing evaluates how effectively the TANGENT Data Catalogue serves its intended purpose in real-world scenarios, ensuring its functionality aligns with the users' needs and expectations.

3.1.1.1 User testing of the TANGENT Data Catalogue

The first version of the TANGENT Data Catalogue, documented in D2.3, was released to partners at M20. To gather opinions and feedback from real users of the catalogue, we designed a set of practical hands-on tasks to be performed by partners on the first version of the Data Catalogue as testing activities within WP7. This testing activity took place from 24th July to 6th September 2023. For the Greater Manchester use cases, various partners from TfGM operational teams were involved.

Users were introduced to the platform by a short video tutorial explaining the basics of the TANGENT Data Catalogue. Then the users were asked to perform a set of tasks to test the catalogue's intended usage and functionalities. As an immediate follow-up to these tasks, users were asked to respond to a survey to collect explicit and implicit feedback. To improve the quality of the feedback received the survey was made anonymous. Explicit feedback was provided by users in the form of a free text response to an open-ended question. Implicit feedback was collected by asking closed questions related to one of the steps required to complete a task. For instance, if a user provides an incorrect answer to a closed question, it could suggest that the user finds the catalogue’s usage unclear, serving as implicit feedback.

A slightly different set of tasks and accompanying surveys was prepared for case study leaders and other partners considering their expected usage of the catalogue. Indeed, case study leaders are expected to use the catalogue to add, edit and browse data sources, while the other users mainly browse available data sources. As such, the tasks and questionnaire were designed to reflect this difference.

As an example, here we discuss a task and the set of associated questions. This task was posed to both case study leaders and technical partners.

Task 1 - Search and analysis of a specific data source

Scenario:

Imagine you need to determine if there was a roadblock in a specific street in Rennes ten days ago. You are invited to check if the "TFGM_CARS_4" data source satisfies your needs.

Your assignment is:

Please search the "TFGM_CARS_4" data source in the data catalogue and read its metadata description to assess its relevance for addressing the need described in the above scenario.

Answers and follow-up questions:

Did you succeed in finding the TFGM_CARS_4 data source?

- *Yes*
    - *Please, describe the steps you did to find the TFGM_CARS_4 data source.*
    - *Based on the metadata description, do you think that TFGM_CARS_4 data source can be used for addressing the need described in the above scenario? Please, justify your answer.*
- *No*
    - *Please describe any problems you encountered while searching for the data source.*

Through this question, several pieces of information can be gathered. By responding "Yes", we first establish that the user was able to perform the task correctly. The follow-up question then gathers details on how the user performed the task, specifically through which series of steps. This answer is crucial as it reveals whether the user was correctly guided through the intended user experience via the catalogue's user interface. If the user followed an unintended path to complete the task, we can use this information to redesign and improve the user experience. The next follow-up question aims to determine if the adopted metadata profile is clear to the user and if it can be used to solve a task that mirrors a potential real-world use case. The most important information is the one gathered when the user is not able to perform the task. This is crucial, as this information is the main driver for significant changes in the catalogue.

Case study (CS) users and other partners (OP) were assigned various tasks. CS users were given more tasks compared to OP users because they have a more active role in utilising the catalogue, including adding and editing data sources. In contrast, OP users primarily engage in searching and browsing the catalogue. Feedback from both user groups was collected on the following tasks:

- Searching for a specific data source and analyse its metadata description (CS, OP)
- Searching for a data source that satisfies a specific data requirement (CS, OP)
- Free exploration of the data catalogue and usage of its functionalities (CS)
- Adding and publishing a new data source into the data catalogue (CS)
- Usage of the dashboard functionality to check the status of data sources (CS, OP)

The questions asked to users after these tasks were designed in the same spirit as the previously described task. Similarly, the answers to these questions were used in a similar vein to drive improvements to the catalogue.

3.1.1.2 In-project testing of the TANGENT Data Catalogue

The TANGENT Data Catalogue is designed to manage the diverse data sources collected from the project's four case studies. This catalogue is not merely a static repository of data and metadata, it is intended to serve as a dynamic, evolving archive that adapts to the project's needs. To facilitate this adaptability and support the project's potential developments, a life cycle has been established for the data sources. Each data source can exist in one of several states, transitioning between them based on specific user actions and conditions set by the TANGENT Data Catalogue Management Board (TMB). The TMB oversees the data quality and governance, ensuring the catalogue remains a robust and responsive tool throughout the project's duration. The list of admissible statuses is the following:

- *Submitted*: When a data source is inserted by a user into the catalogue.
- *Published*: When a data source is reviewed by the TMB and approved for publication.
- *Rejected*: When a data source is rejected after a review by the TMB because it is found to not be useful or applicable to the project.
- *Incomplete*: When a data source lacks certain required metadata fields that have not been filled out by the user. The data source is sent back to the user with a request for further information.
- *Not accessible*: A specific case of incomplete metadata where the data source description lacks the access URL to the actual data it describes.

Regarding the in-project testing activity, we report on the number of data sources collected through the TANGENT Data Catalogue and approved for usage within the TANGENT project for the Manchester Case Study.

3.1.2 Actions achieved and results

In the following, we report the aggregated results obtained for the user testing of the TANGENT Data Catalogue and the results of the in-project testing for the Manchester case study.

3.1.2.1 User testing of the TANGENT Data Catalogue

The user testing activity involved 14 partners acting as case study leaders and 9 other partners. From these groups, the survey aimed at gathering constructive feedback for the TANGENT data catalogue received responses from 9 out of 14 demo leaders and 3 out of 9 other partners. The testing activity was conducted using the first version of the TANGENT Data Catalogue, described in detail in D2.3 and shown in Figure 4.

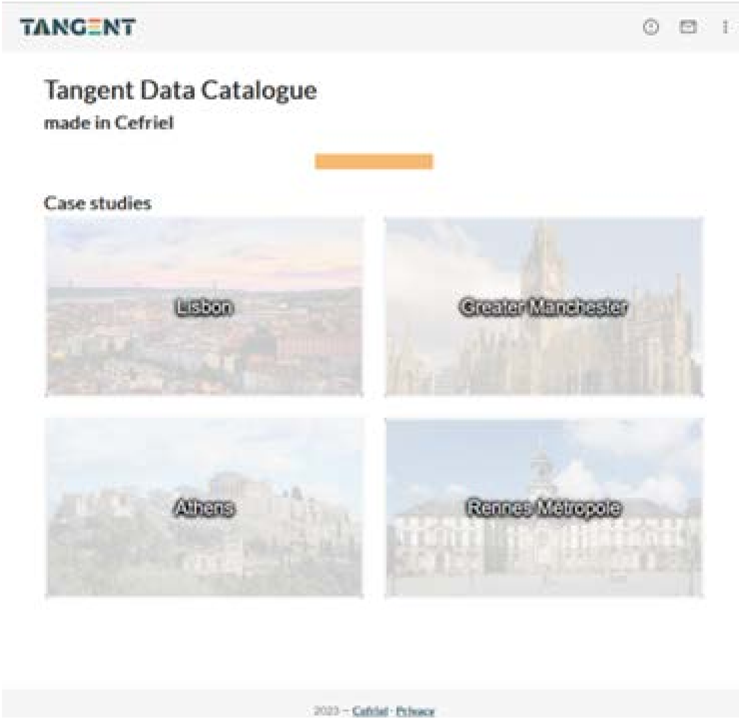

Figure 4: Homepage of the first version of the TANGENT Data Catalogue

After analysing the current survey responses on the testing of the TANGENT data catalogue, the main areas for improvement have been identified as follows:

- **Search Capabilities and Interface**: Numerous feedbacks indicated the need for enhanced search functionality, specifically the ability to search by metadata attributes that are not currently available as filter options. Additionally, the filtering capabilities offered through the user interface could be made less confusing and more user-friendly.
- **Dashboard Information and Interactivity**: The information displayed on the dashboard needs to be expanded and made more interactive. Users have expressed a desire for a more detailed and engaging dashboard experience.
- **Action Feedback**: Certain actions, such as submitting a data source for publication, currently lack feedback mechanisms that inform the user of the action's result. Providing clear and immediate feedback for these actions would improve the overall user experience.

Based on the feedback we gathered, it became evident that a small but notable portion of users experienced difficulty in successfully completing one of the tasks associated with locating a specific data source. This feedback was collected through both quantitative and qualitative methods. Quantitatively, we measured how many users were able to find the data source. Qualitatively, we invited users to provide open-ended feedback detailing the challenges they faced during this task. This dual approach allowed us to capture not only the extent of the issue but also the specific problems encountered, offering a comprehensive understanding of the user experience and the obstacles they encountered. The answers received for task 2 serve as an excellent example of this quantitative aspect, as is shown in Figure 5.

Scenario: A project partner tells you that a data source satisfies the "WEATHER_DATA" data requirement for your case study.

Your assignment is: Try to find the data source in the data catalogue. Read its metadata description carefully.

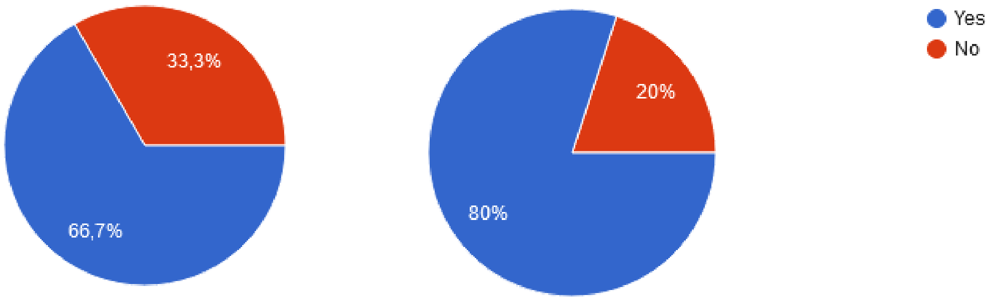

Figure 5: On the left the percentage of case study leaders who completed task 2; on the right, the percentage for other partners

By addressing these issues, the final version of the TANGENT Data Catalogue improves upon the first release by introducing new functionalities and improving the user experience. For example, the homepage has been changed to show the latest uploaded data sources, which helps users know the latest changes in the catalogue. Additionally, because users often access the catalogue to search for a specific asset, a search box and corresponding search functionality have been added to the homepage.

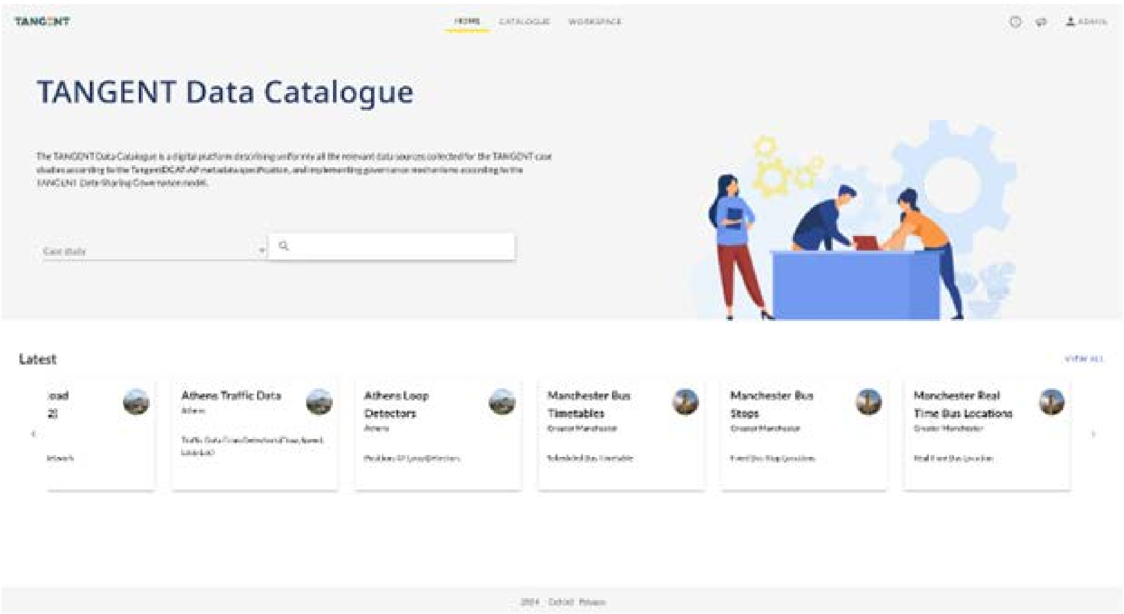

Figure 6: Homepage of the final version of the TANGENT Data Catalogue

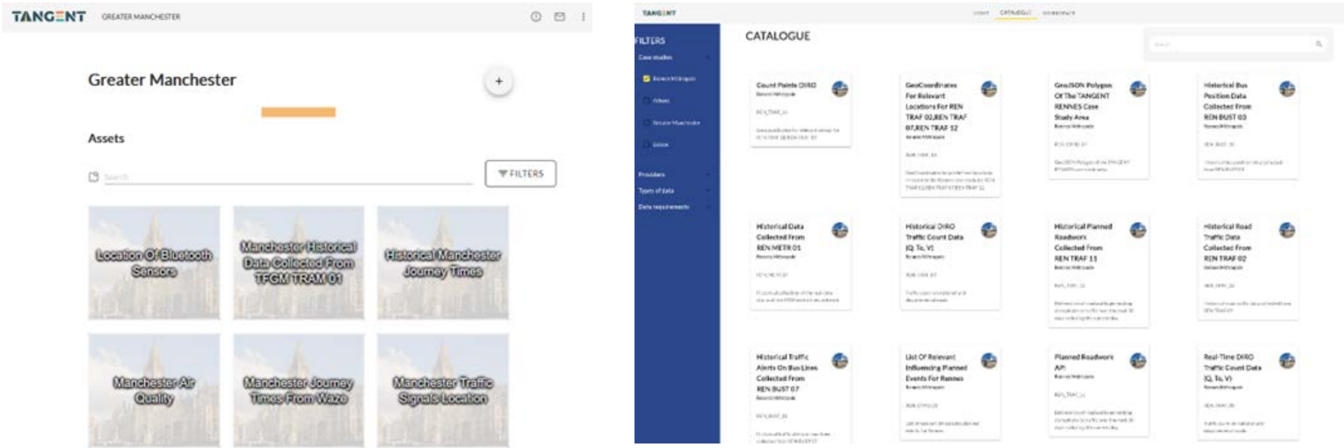

Figure 7: Search functionalities in the different versions of the Tangent Data Catalogue

A site-wide change has been made to separate different functionalities offered by the TANGENT Data Catalogue. As can be seen in the top part of Figure 6, the final release of the catalogue is divided into three main areas: the home, the catalogue and the workspace. As previously described, the homepage is designed to bring the user up to date with the latest changes and offer the shortest possible path to one of the most common interactions with the catalogue, i.e., searching. The catalogue area, shown in Figure 7, allows the user to browse all the data sources available in the catalogue and perform more fine-grained searches. Indeed, as searching and filtering were identified as the main areas of interest during the testing of the first release of the data catalogue, the UI and UX for this functionality were particular points of focus. While the previous version of this page was found to be confusing to users, especially because it was not readily apparent what filters were currently active, the new and improved version clearly shows the active filters on the left side of the page and the used keyword in the search box. Additionally, with this layout, more results can be displayed, making it easier for users to manage searches that retrieve an extensive set of results. Lastly, the workspace area is entered when acting on a single data source or to access an overview of the state of the whole catalogue or the state of the data sources owned by the current user.

3.1.2.2 In-project testing of the TANGENT Data Catalogue

For the Manchester use case, a total of 47 data sources were collected and submitted through the TANGENT Data Catalogue. After careful review and discussion with relevant project partners, the TANGENT Data Catalogue Management Board (TMB) determined that 13 of these data sources were not relevant and subsequently rejected them. Of the remaining data sources, 31 met the project's data quality requirements and were approved for use. One data source remained inaccessible and was not utilized by any partners, while two others were submitted with incomplete metadata.

3.2 Choice model for Synchronization of Public transport and traffic control & Choice model for Dynamic Congestion Pricing (WP3)

The principal output of WP3 is the travel choice module, an analytical tool for modelling travel decision-making under various mobility scenarios. The module, the development of which is thoroughly described in D3.2 and schematically described in Figure 8, builds upon input data elicited using the Travel Behavior Survey (TBS), a structured stated-preferences questionnaire that captures commuters' sociodemographic traits, travel patterns, perceptions of system-level attributes, and preferences for different travel options. At its output, the machine learning and econometric models at its core predict mode choice decisions and identify significant factors influencing commuter decisions.

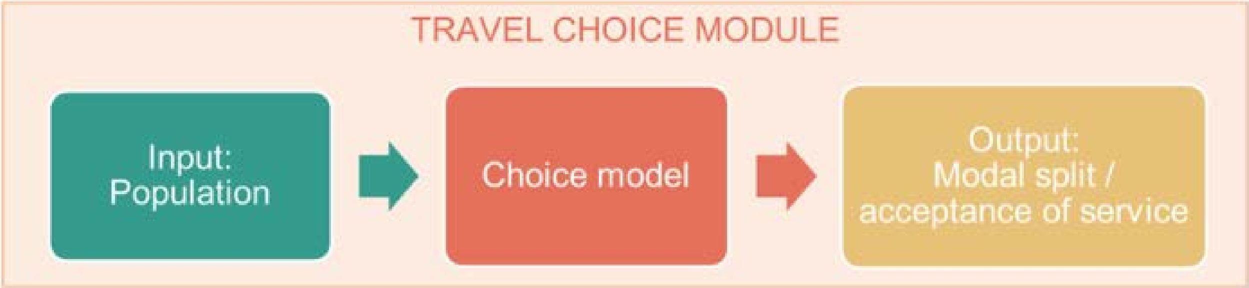

Figure 8: Travel Choice Module inputs & outputs

Given the design of the modelling framework, the testing of the module aims to ensure that all interface points between the module and the population whose behaviour is modelled fulfil expectations.

- Upstream, the survey's ability to effectively capture commuter behaviours must be assessed, best achieved through recipient feedback on its clarity, relevance, and effort needed.
- Downstream, it is necessary to evaluate whether the model's predictions align with common intuitions about travel behaviour in specific cities, with local commuters being again the most qualified evaluators.

As a result, a four-step testing methodology for the WP3 travel behaviour module is developed based on commuter feedback and presented in the sections that follow.

The collected user feedback is critically analysed, offering valuable insights for the development of similar mode choice modules. This methodology is further discussed in the section that follows. Given that the consolidated testing process for all case studies, the sections that follow are virtually identical for D7.3/4/5/6.

3.2.1 Methodology

Step A: Testing sample collection

During the initial phase of testing, the Travel Behavior Survey (TBS) was distributed to commuters from each case study city, including Manchester. The objectives of this phase are to:

- Familiarise testers with the questionnaire's content and design by having them take the survey themselves.
- Provide the necessary data for executing the travel behaviour module (Step B).
- Obtain the contact points of testers (email addresses) for the distribution of the feedback survey of Step C.

The TBS questionnaire is included in the Annex of D3.2.

To collect the necessary sample, each case study was asked to identify 10 commuters from various age, gender, profession, and usual transport mode groups who had not taken the survey before. With their contact details, the testers were contacted by NTUA with instructions on how to complete the TBS.

Step B: Execution of the travel behaviour module

Following the collection of testers' responses, the mode choice models in the travel behaviour module were launched, and their predictions about the factors affecting mode choices were converted into simple, non-technical language. The text communicated to the testers is provided below.

One of the key advantages of the models that we have created is that they are able to reveal the factors that affect commuter's travel choices. Specifically, we have found that:

- *The probability to use a private car over public transport is higher among younger commuters and among commuters with higher incomes.*
- *Increased satisfaction with the public transit system correlates with a higher likelihood of choosing public transportation over a private car.*
- *Rising costs and extended travel times, whether for cars or public transport, diminish the appeal of these modes, leading to a shift towards alternative travel options.*

Step C: Feedback Survey

As an immediate follow-up to these tasks, users were asked to complete a second feedback survey to assess the clarity, interpretability, and intuitiveness of the questions, the time and effort necessary to complete the TBS, and opinions on whether the modelling insights are deemed logical and in line with the testers' expectations.

The survey contained 10 questions, with an estimated completion time of 5 minutes. To ensure honesty in the responses, the survey was anonymous. With the contact details from Phase A, NTUA directly disseminated the feedback survey from 14/02/2024 to 19/02/2024.

Tester feedback was collected using closed questions with predetermined, multiple-choice or scale-based answers. The first question of the questionnaire is provided as an example below.

Figure 9: On a scale of 1 to 5, how easy was it to understand the purpose of the questionnaire?

For specific questions requiring in-depth, qualitative insights that closed-ended questions could not capture, respondents were requested to provide their answers in a free text format to an open-ended question, as illustrated below.

Can you point out some of the questions that you found confusing or ambiguous?

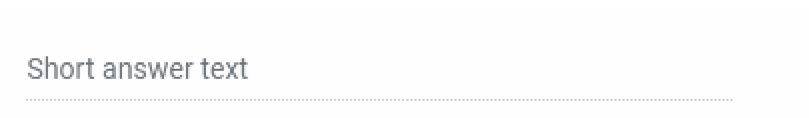

Figure 10: Free text format for open-ended questions

Step D: Reporting on the results

The feedback collected during the testing is presented in the "Results" section that follows. Some results have already been presented internally to the consortium during the WP7 bi-weekly meetings dedicated to subsystem testing and the consortium's monthly audio meetings.

3.2.2 Actions achieved and results

A total of 42 commuters from all case studies have been contacted by case study leaders and NTUA, out of which 11 have responded to the feedback survey.

Their responses are pooled together, translated into English and analysed below on a question-by-question basis.

Initially, respondents were asked to evaluate how easy it was to understand the purpose of the questionnaire (Figure 11), rating their experience on a scale from 1 (not clear at all) to 5 (very clear). The majority (81.9%) evaluated their understanding as either 4 or 5, suggesting the effectiveness of the introductory materials and instructions provided with the questionnaire.

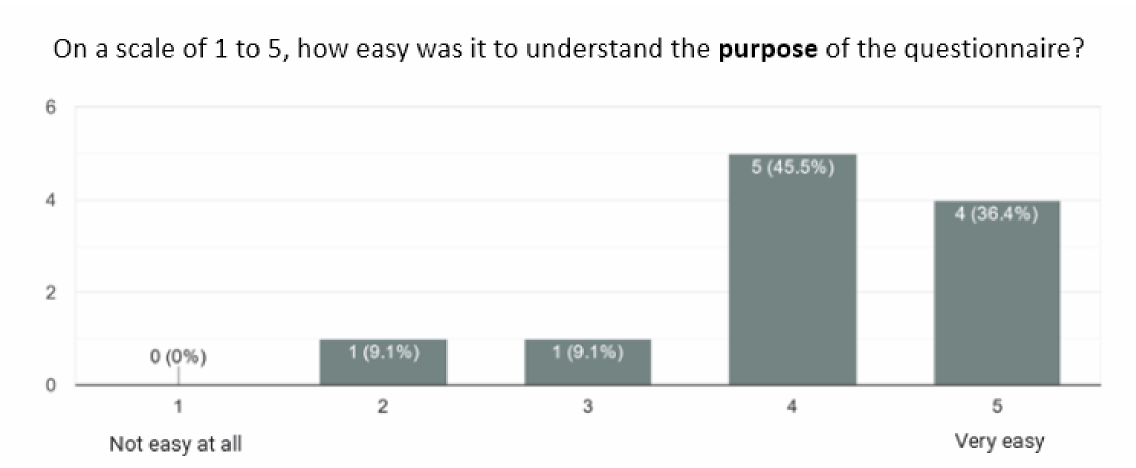

Figure 11: On a scale of 1 to 5, how easy was it to understand the purpose of the questionnaire?

This good understanding of the overall questionnaire can also be attributed to its questions being clear and intuitive. In the relevant question (Figure 12), where an evaluation of 1 suggests that questions were not clear at all and an evaluation of 5 suggests that questions were very clear, the majority of respondents (63.7%) responded with 4 or 5, while respondents (27.3%) found the questions to be moderately clear by selecting "3".

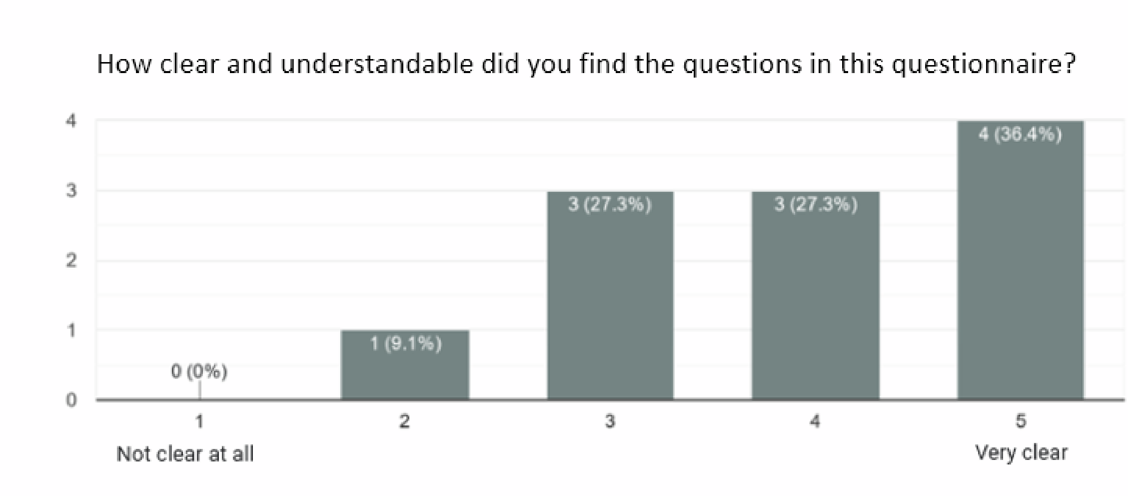

Figure 12: How clear and understandable did you find the questions in this questionnaire?

Two comments were also received in response to the open-ended question on how the overall clarity of the questionnaire can be improved. One respondent suggested the inclusion of a working-from-home option, and a second one suggested that the scale of some questions was somewhat unclear. This feedback can be attributed to Google Forms' practice of providing linguistic interpretations only for the extreme values (1 and 5), leaving the middle scale values as numbers, which can result in some ambiguity.

On a follow-up question of whether the TBS questions were in-context, the vast majority of respondents (81.8%) found all the questions to be relevant, suggesting that the survey was contextually appropriate.

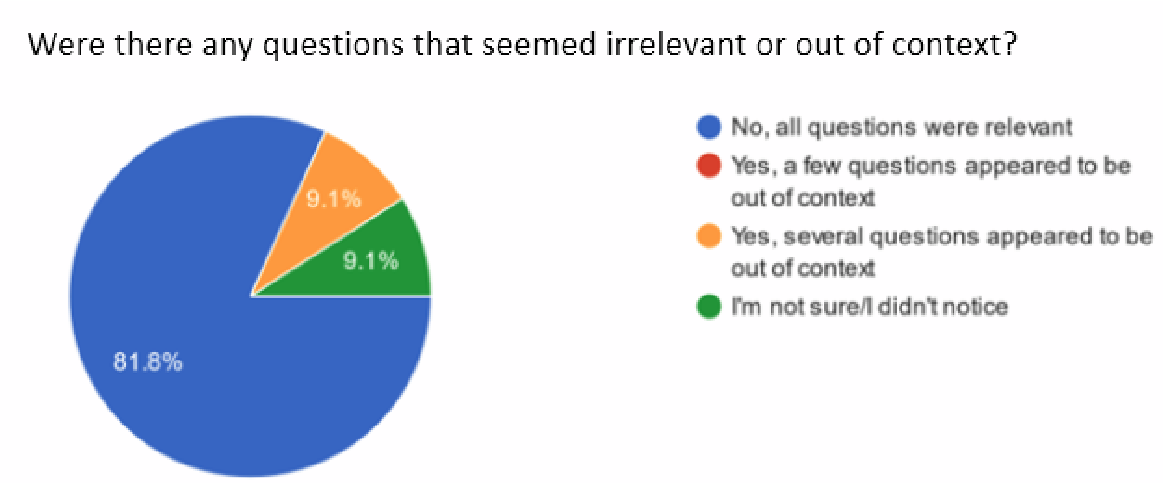

Figure 13: Were there any questions that seemed irrelevant or out of context?

On the overall layout and formatting of the questionnaire (Figure 14), the majority of respondents (54.6%) rated it as either 4 or 5 (good or excellent). Another 36.4% rated it as satisfactory.

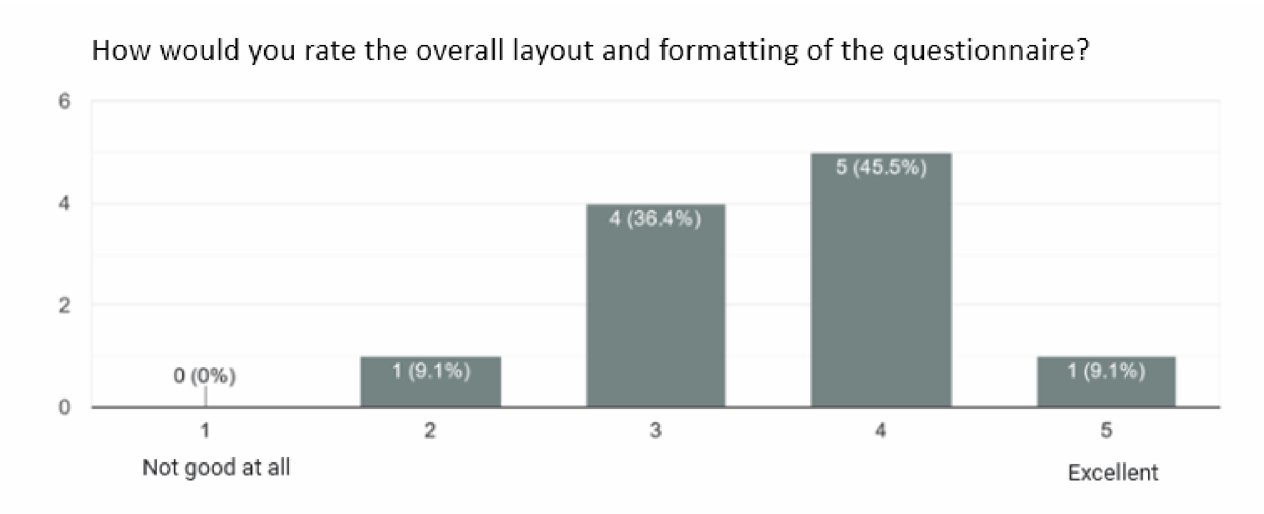

Figure 14: How would you rate the overall layout and formatting of the questionnaire?

Regarding the length and completion time of the questionnaire (Figure 15), most respondents perceived the survey as either appropriate or somewhat lengthy (chart on the left). While this feedback indicates a potential need to shorten the survey to enhance participant satisfaction, the suggestion must be weighed against the benefit that a longer questionnaire allows for the elicitation of more detailed information concerning commuters' mode choice decisions. Considering that 91% of respondents completed the survey within the estimated 15-minute timeframe deemed necessary by the study team (chart on the right), it can be concluded that the completion time was appropriate for the questionnaire's length.

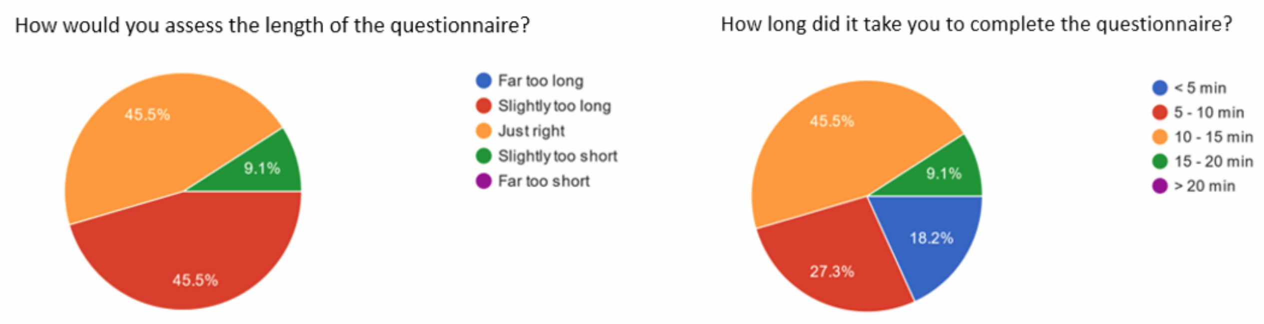

Figure 15: How would you rate the length and completion time of the questionnaire?

Finally, two respondents emphasised the need to revisit and edit previous answers in future questionnaires response to a general open-ended question that elicits overall comments or suggestions on the content and format of the questionnaire. They highlighted that once a page of responses was submitted, it was not possible to return and make corrections.

Modelling insights

In the concluding section of the questionnaire, participants assessed the factors influencing travel choice decisions, as presented in Section B. The overall feedback (Figure 16) indicates that most respondents found the results logical and consistent with their expectations regarding transportation choices, with 63.7% rating their agreement as 4 or 5 (indicating complete agreement with the analysis).

Three respondents (27.3%) rated their agreement as 3, suggesting neutrality while one respondent expressed total disagreement but did not provide an explanation in the follow-up question.

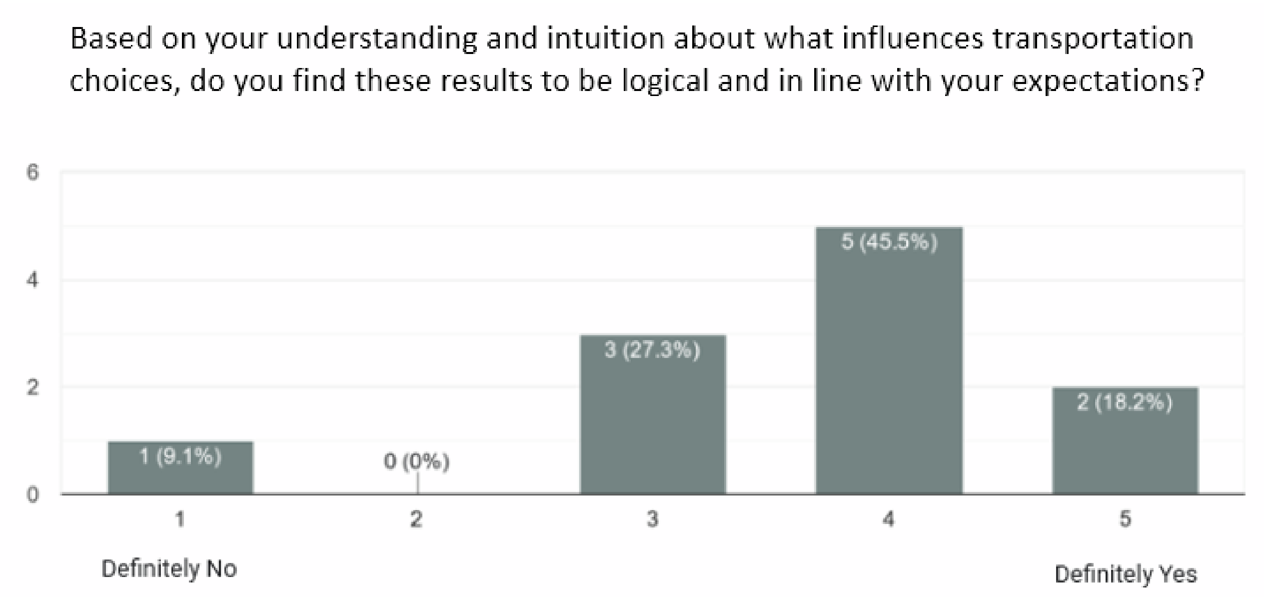

Figure 16: - Based on your understanding and intuition about what influences transportation choices, do you find these results to be logical and in line with your expectations?

Concluding, the open-ended question on whether there are additional factors that significantly influence travel choice decisions and could be examined in future models received 5 comments. These comments mentioned the frequency, adherence, reliability, accessibility, and comfort of public transport, as well as the ability to work from home.

3.3 Supply Forecasting & Critical conditions (WP4)

In WP4 deep learning methods were developed to forecast traffic supply. The forecasting methods are applied to the four case studies of the TANGENT project. Results are considered per case study, and are described via different steps, including data pre-processing, training the models, determining forecasting accuracy, etc. in Deliverable 4.2 “Overview of the developed traffic supply forecasting approaches with benchmarks”. The developed anomaly detection algorithm is included in Deliverable 4.4 “Report on the detection and impact analysis of traffic events”, where the results were shown for the case studies of Greater Manchester and Athens.

For the case study of Greater Manchester, the supply forecasting results of 2 datasets were described in Deliverable 4.2, namely the journey time and traffic counters datasets. The journey time dataset consists of a time series for each route, representing the time it takes to drive from point A to point B. TfGM defined the routes of interest in the study area (204 routes). The journey times are given with a 15 minutes time step for a duration of 12 months (2022-01-01 00:00:00 to 2022-12-31 23:45:00). The traffic counter dataset shows the number of vehicles in different vehicle types and speed categories with a resolution of 5 minutes and a duration of 13 months (1st January 2022 to 31st January 2023).

After submission of D4.2 an extra supply forecasting model for public transport For Greater Manchester was built. For TfGM bus travel time prediction, the pre-processing steps described in D4.2 are applied. The average speed and travel time for each grid are calculated and are used as input to the first model that makes grid-level travel time predictions. The output of the first model is then fed to a deep learning pipeline to predict line-level travel times. The description in D4.2 (for Rennes bus travel time prediction) was based on an extraction of the grids that need to be passed from origin to destination, which were aggregated manually. This procedure was extended to a data-driven procedure based on a transformer architecture. The journey time for each individual bus is calculated by grouping the journeys based on the vehicle ID, aimed departure and aimed arrival time. Because of the extreme sparsity of the travel times, an imputation procedure is applied in a sequential process. It first tries to impute the missing values based on the average values of the past week for the same hour. Then checks again for the remaining missing values and tries to impute based on the average values of the past days for the same hour. Extra options for remaining missing value imputation are average values for the past hours, or even a mean travel time. Cyclical time features are concatenated to the grid journey times to provide better context to the model for better accuracy. The model takes the grid journey times together with the time features as input and predicts the bus travel times.

Furthermore, TfGM asked to broaden the case study area. This resulted in larger supply forecasting models compared to the one described in D4.2, both for journey time prediction as for the predictions based on traffic counters. For the latter, an overlap of the historical and the real-time segments were considered for the broader region, and models were retrained on those overlapping segments. Furthermore, the temporal resolution differed between the trained models and the real-time data feed. Therefore, this was also considered in the retraining of these models.

As shown in D4.2, journey time prediction models were built for the TFGM_CARS_04 dataset. Unfortunately, the sensors went out of service after the forecasting model was trained and deployed. Testing, however, was performed on this journey time prediction model.

We then received Waze historical travel time from TFGM and trained models and trained a model that uses the last 4 hours to make a 1-hour prediction. This model has a MAE of 34.76, MAPE of 11.34% and RMSE of 55.89. We depict a sample prediction in the next section.

3.3.1 Methodology

Both supply forecasting and anomaly detection were tested by the case study leaders. The testing methodology is described in this section.

Preparation phase:

- Meeting with case study leaders to discuss the priorities related to supply forecasting and anomaly detection, which datasets are best suited, most interesting to predict, etc.
- Back and forth communication about datasets, defining testing methodology, etc.

Predictive model building:

- Build models for the different datasets of Greater Manchester for supply forecasting, as described in D4.2 and D4.4
- Collection and analysis of the results in maps
- Share results and main conclusions with case study leaders
- As described in the introduction more predictive models were built after the submission of D4.2, therefore these are added in this deliverable.

Feedback:

- The case study leaders provide feedback based on the maps
- In the second stage this feedback can be based on the live dashboard
- Extra requests from the case study leaders were also considered, as described in the introduction of this section (broaden case study area, add public transport)

Details regarding the steps above are included below:

Before the supply forecasting and anomaly detection results were added to the live dashboard, the results were shared for testing purposes with the case study leaders. Folders with maps were shared, together with guidelines on how to provide feedback related to the testing.

Supply forecasting: access to results
After unzipping the files from the testing folder, you'll find an HTML file alongside a "timeseries" folder The HTML file serves as a map, pinpointing the sensors used in the dataset. Clicking on the blue markers will display the sensor's name and prediction error for various horizons. Each prediction horizon represents a 5-minute interval. For instance, horizon 1 corresponds to a 5-minute prediction, while horizon 12 equates to a 1-hour predictions. This data encompasses all sensors and prediction horizons. The folder contains interactive HTML files, allowing you to zoom in and out and pan across the time series. Missing values are represented by 0 in the ground truth. For the TFGM5_Speed dataset, the average Mean Absolute Error (MAE) is 1.963 mph, and the TFGM5_COUNT dataset has an average MAE of 8.143 cars per interval. You can also find the individual MAEs for each sensor detailed in the charts and the map file.

Table 1: Supply forecasting: access to results

Supply forecasting: procedure for testing & providing feedback
Then please follow the following procedure: 1. Pick days, times, and locations that interest you. 2. Act as if it's real-time that moment 3. Look at predictions for that time for the upcoming minutes. 4. Check the actual values. Do they correspond? Is this what you expected?

Table 2: Supply forecasting: procedure for testing & providing feedback

Extra information was shared via meetings/mails to make sure the presented information was well understood by the case study leaders.

Similarly, results related to anomaly detection were shared.

Anomaly detection: access to results
After unzipping the files from the testing folder, you'll find a "timeseries" folder. Inside this folder, you can access the time series data for horizon 1 predictions (red charts), their corresponding ground truths (blue charts), normalized anomaly scores (in brown), and detected anomalies in orange vertical lines. Lower anomaly scores represent a higher chance of anomalies. Missing values are represented by 0 in the ground truth. You can use the same map provided for supply forecasting to extract the location of each sensor.

Table 3: Anomaly detection: access to results

Anomaly detection: procedure for testing & providing feedback
Please structure your response in the rows below: 1. Pick days, times, and locations that interest you. 2. Act as if it's real-time that moment 3. Look at detected anomalies for that time for the upcoming minutes. 4. Is this what you expected? 5. Specifically, are there anomalies the model couldn't detect (False Negatives)? 6. Specifically, are there any instances in which the model detected an anomaly, but those are not anomalies (False Positives)? 7. How do you look at these predictions? Do you wait for anomalies to be detected and start traffic management from there, or do you already adjust traffic based on the supply predictions?

Date and time	**Locations (Sensor_id)**	**Output_of_the_algorithm**	**Desired_result (Qs 4-5-6)**	**Notes**

Table 4: Anomaly detection: procedure for testing & providing feedback

3.3.2 Actions achieved and results

The case study leaders of Greater Manchester listed some COSIT (TFGM_CARS_04) and Site IDs (TFGM_CARS_05) relevant to matchday and event scenarios. This input is shown in the figure below.

Date and time	Locations (Sensor_id)	Notes
24/10/2023	1415	Old Trafford Match 20:00
24/10/2023	1432	Old Trafford Match 20:00
24/10/2023	1410	Old Trafford Match 20:00
24/10/2023	9800WB0ICA90	Old Trafford Match 20:00
24/10/2023	9800YRLLBRCS	Old Trafford Match 20:00
24/10/2023	9800ZJIIWFWW	Old Trafford Match 20:00
03/10/2023	1415	Old Trafford Match 20:00
03/10/2023	1432	Old Trafford Match 20:00
03/10/2023	1410	Old Trafford Match 20:00
03/10/2023	9800WB0ICA90	Old Trafford Match 20:00
03/10/2023	9800YRLLBRCS	Old Trafford Match 20:00
03/10/2023	9800ZJIIWFWW	Old Trafford Match 20:00
26/09/2023	1415	Old Trafford Match 20:00
26/09/2023	1432	Old Trafford Match 20:00
26/09/2023	1410	Old Trafford Match 20:00
26/09/2023	9800WB0ICA90	Old Trafford Match 20:00
26/09/2023	9800YRLLBRCS	Old Trafford Match 20:00
26/09/2023	9800ZJIIWFWW	Old Trafford Match 20:00
11/10/2023	1411	AO Arena Event 20:00 (Madonna)
11/10/2023	1419	AO Arena Event 20:00 (Madonna)
11/10/2023	1274	AO Arena Event 20:00 (Madonna)
11/10/2023	9800XP0NQGE7	AO Arena Event 20:00 (Madonna)
11/10/2023	9800ZLVVYT19	AO Arena Event 20:00 (Madonna)
11/10/2023	9800ZRUSHAHB	AO Arena Event 20:00 (Madonna)
02/06/2023	1411	AO Arena Event 20:00 (Elton John)
02/06/2023	1419	AO Arena Event 20:00 (Elton John)
02/06/2023	1274	AO Arena Event 20:00 (Elton John)
02/06/2023	9800XP0NQGE7	AO Arena Event 20:00 (Elton John)
02/06/2023	9800ZLVVYT19	AO Arena Event 20:00 (Elton John)
02/06/2023	9800ZRUSHAHB	AO Arena Event 20:00 (Elton John)
22/09/2023	1411	AO Arena Event 20:00 (Peter Kay)
22/09/2023	1419	AO Arena Event 20:00 (Peter Kay)
22/09/2023	1274	AO Arena Event 20:00 (Peter Kay)

Figure 17: Feedback from case study leaders Greater Manchester on supply forecasting and anomaly detection

Unfortunately, these dates weren't part of the test set, which was depicted from the historical data. Therefore, other dates were checked for the location near Old Trafford, namely Wednesday, December 21st, 2022 and Tuesday December 27th, 2022, when Manchester United played in the English League Cup and English Premier League respectively. As can be seen in the graphs below, the observed speeds indeed tend to be lower on these specific days, but the predictions are able to keep up with the decrease in speed. Different horizons are depicted. Horizon 1 corresponds to 5 minutes ahead in time, horizon 3 to 15 minutes, while horizon 12 corresponds to 1 hour ahead. The latter of course is harder.

Figure 18: Speed prediction and ground truth in Horizon 1 - 21/12/2022

Figure 19: Speed prediction and ground truth in Horizon 1 - 27/12/2022

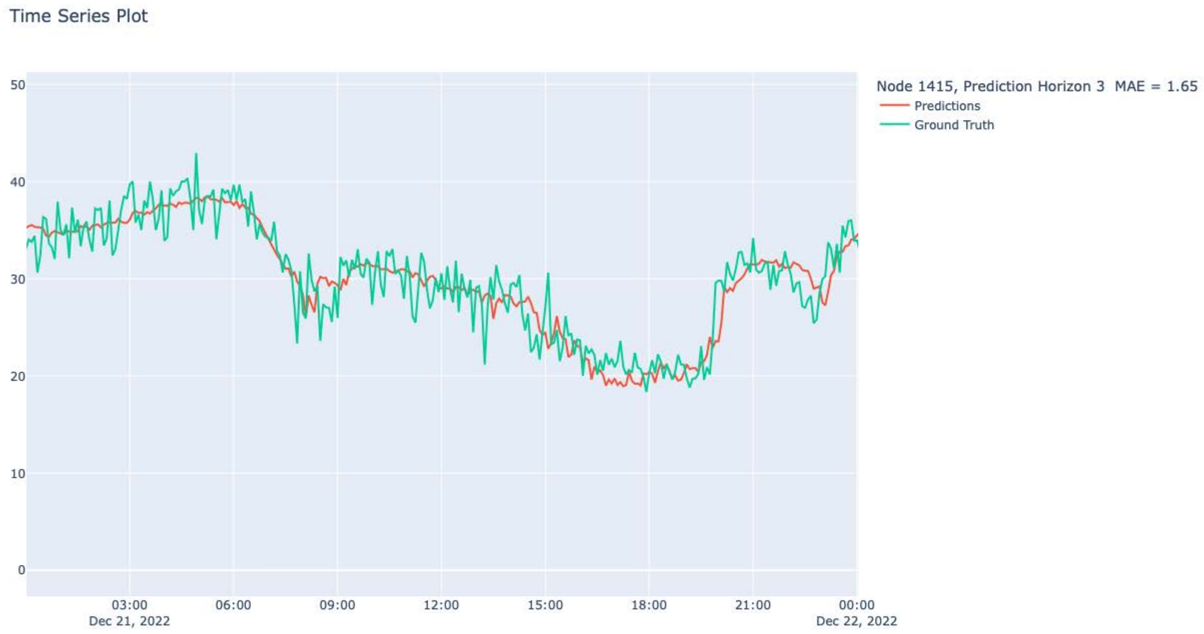

Figure 20: Speed prediction and ground truth in Horizon 3 - 21/12/2022

Figure 21: Speed prediction and ground truth in Horizon 3 - 27/12/2022

Figure 22: Speed prediction and ground truth in Horizon 12 - 21/12/2022

Figure 23: Speed prediction and ground truth in Horizon 12 - 27/12/2022

Some sample results on the Waze dataset are depicted below. The green lines show the ground truth and the red line indicates the predictions. When the green line is at 0, it indicates that the value is missing at that time. The charts are showing 1-hour predictions.

Figure 24: Waze data prediction and ground truth in Horizon 4 – May 28 to June 3

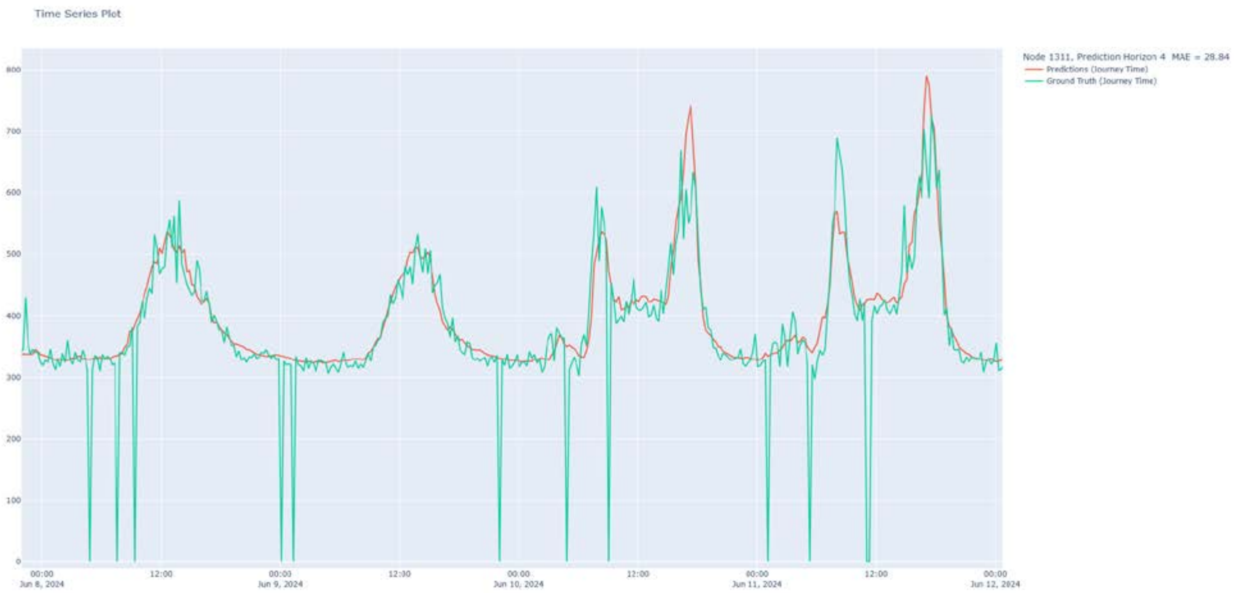

Figure 25: Waze data prediction and ground truth in Horizon 4 – June 8 to June 12

3.4 Demand Estimation & Prediction (WP4)

3.4.1 Methodology

In WP4, AIMSUN developed a novel method to estimate the demand, which does not rely on simulation evaluations, rather on Machine Learning (ML) - based and optimization approaches. The benefits of the proposed demand estimation model are demonstrated as a proof of concept through the case study of Manchester. In particular, dynamic (time-dependent) demand matrices were estimated for a whole day and a given traffic pattern (representing a month in November 2022), having only available a flat (static) OD matrix for the evening peak hour and time series of observed traffic counts.

For the case study of Manchester, a calibrated transport simulation model in Aimsun Next was provided by Transport for Greater Manchester (TfGM), which was used to extract the previously calibrated base demand, representing an average day with normal traffic conditions based on real data from November 2022, as provided by TfGM. In particular, the OD matrix for the study area of interest contains 109 centroids and has a total demand of 32529 vehicle trips grouped into two main types, namely cars and trucks. This travel demand represents a day with normal traffic conditions in the network and has a duration of one hour, from 17h to 18h. Regarding the traffic flow measurements, historical data was retrieved from 24 automatic counter locations with a time interval of 15 minutes and for the period of one month, from 2022-11-01 to 2022-11-30. The historical base demand and traffic measurements were used as input to the developed ML-based demand estimation approach.

3.4.2 Actions achieved and results

The following actions were performed in relation to the data-driven demand estimation (Manchester case study):

- Historical traffic data from November 2023 were extracted using the data catalogue of Manchester. This data was used to identify different traffic patterns to be used as input for the demand estimation
- Application of the developed data-driven method.
- Analysis of the results
- Preliminary validation tests comparing the results from the demand estimation using the current simulation-based algorithm of Aimsun Next with the results generated by the proposed ML-based demand estimation approach
- Documenting the results in respective deliverables
- Online meetings with TfGM to discuss the results

The proposed method provides methodological and practical contributions to overcome known issues of the demand estimation problem, as reported in Deliverable 4.3 “Overview of the developed travel demand predictions with benchmarks”. The key benefits of the proposed method are that it generalises well through small- and large-scale networks, is fast in terms of computational time, requires little parameter fine-tuning and can work over different types of days recognizing that traffic patterns change from one day to another.

The adjusted matrices provided a more accurate demand to be further used as input to simulation-based analyses (what-if scenarios and network optimization) for traffic management applications. The proposed method and preliminary results from the application to the Manchester case study are presented in Deliverable 4.3.

3.5 Transport model building for simulation-based analysis

As presented in D7.1 “Definition of the Case Studies, testing methodology and stakeholders' & users' engagement campaign” and D7.2 “System deployment and testing specifications”, the Greater Manchester case study has listed what-if simulations to build according to their specificities and challenges. The following section presents the tests results of the simulations carried out by AIMSUN.

3.5.1 Promotion of PT and DRT services for events/matchdays

This set of What-if scenarios intends to perform a simulation impact assessment of the introduction of Public Transport (PT) priority to specific bus lines. More specifically, prioritisation of PT is considered through the synchronisation of PT and traffic signal plans.

A preliminary analysis is performed to study the impact of a potential demand shift of car trips to public transport, focusing on days with special events in the network of Manchester (i.e. football matches). Various simulation scenarios with different penetration rates for this demand shift are examined. To ensure that the potential mode shift from cars to public transport can be satisfied by the current bus lines, an increase in the frequency of select lines is also considered in the experimental design.

Following, optimisation of the traffic signal plans is performed for each of the pre-defined scenarios, aiming to reduce the traffic network and PT service performance.

3.5.2 Description of simulation scenarios

A transport simulation model is available Manchester model in Aimsun Next, which includes a calibrated demand that corresponds to a day with an event in the network. In particular, a day with a football game at the Old Trafford (Man Utd´s) Stadium. The scenario representing the demand on an event day is considered as the baseline for the following what-if scenarios.

For the scope of the analysis, two key centroids located near the stadium are considered as the affected ones for which modal shift from car to public transport is assumed (Centroid IDs: 146002029, 14602195). Figure 26 depicts the network of Manchester with the selected centroids and the trip connections that they attract during the study period.

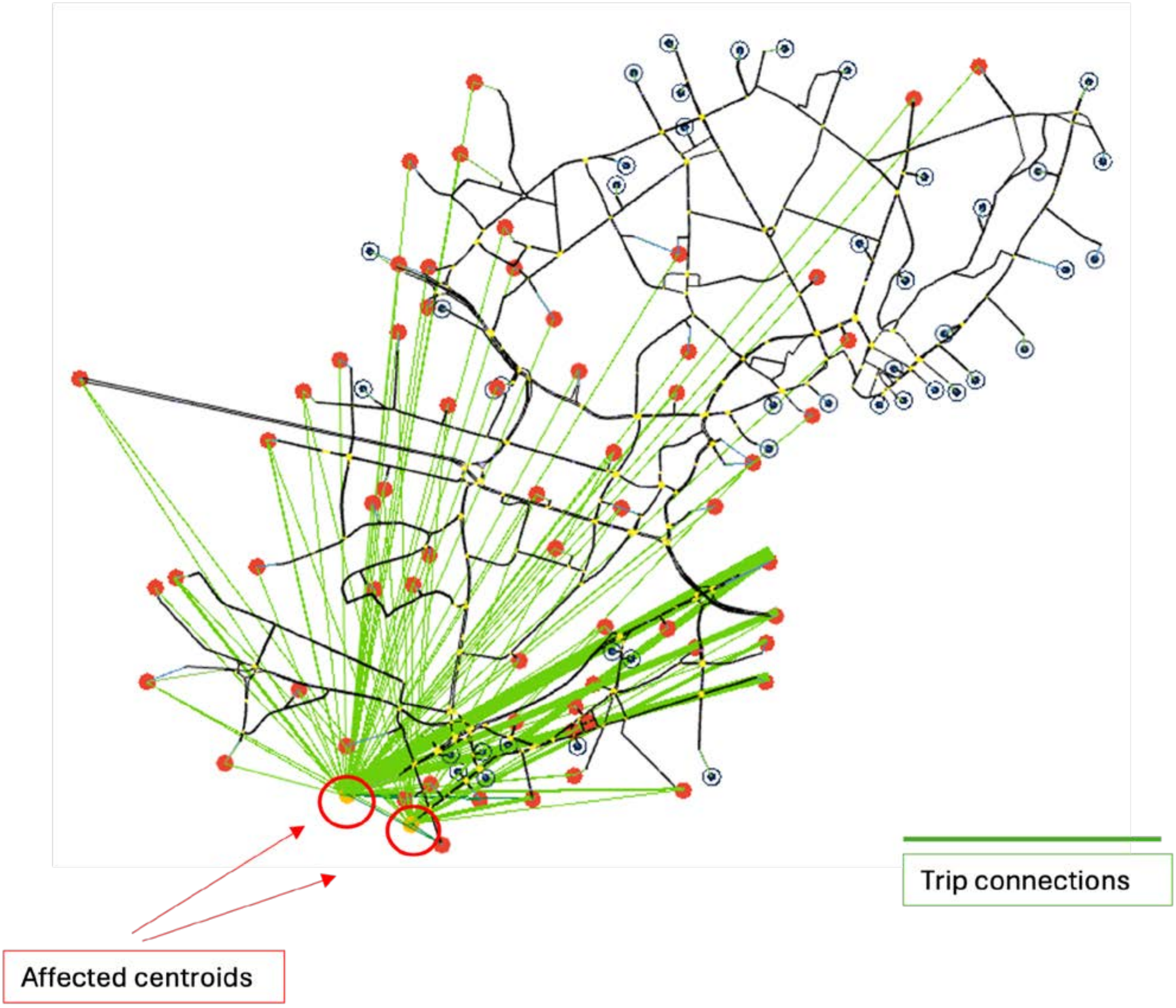

Figure 26: Manchester simulation model in Aimsun Next, highlighting the two centroids selected for the demand shift and their trip connections.

The following scenarios are investigated, assuming varying percentages of car trips shifting to public transport on the day with an event. Two relevant public transport lines are considered due to their proximity to the stadium; lines X50 and 250. The optimisation of the traffic control plans is performed for the intersections that are relevant for the select bus lines.

The percentages correspond to the demand shift only of the trips that have as destination the two selected centroids during the simulation period (17:00 – 18:00). In total, the two centroids attract **1469 car trips** during the study period. In comparison to the total demand in the network, the considered demand shifts to public transport correspond to a reduction of 1%-3% of the car trips.

Table 5 provides a summary of the examined What-If scenarios for Manchester.

What-If simulation scenarios	Description	Number of car trips shifted to PT
1. Baseline EVENT day evening peak scenario	Baseline scenario for the demand that corresponds to the event day (17:00 - 18:00)	-
2. Scenario with 20% PT shift & increased frequencies	These scenarios assume different percentages of car demand trips that are shifted equally to PT lines X50 and 250. The number of car trips is reduced in the baseline scenario and the frequencies of the PT lines are increased proportionally to serve the new demand	294
3. Scenario with 40% PT shift & increased frequencies		588
4. Scenario with 80% PT shift & increased frequencies		1175
5. Scenario with 20% PT shift & increased frequencies & optimised traffic control plans	Same as the scenarios above. In addition, the traffic control plans are optimised for each scenario with different penetration of demand shift to PT	294
6. Scenario with 40% PT shift & increased frequencies & optimised traffic control plans		588
7. Scenario with 80% PT shift & increased frequencies & optimised traffic control plans		1175

Table 5: Description of the Manchester what-if simulation scenarios for promotion of public transport on days with events

Depending on the demand change, different assumptions are made regarding the required bus frequency adjustments to serve the “new” demand for bus lines X50 and 250. Table 6 presents the baseline and the new frequencies for the different demand shift percentages, respectively. For the scope of this study it is assumed that the current PT lines are operating at full capacity due to the fact that the study period represents a day with a football match. Hence, additional buses are needed to serve the demand to be shifted from cars to public transport. As a rule of thumb, each bus is assumed to have an occupancy of 50 persons, hence for any additional 50 passengers an extra bus is assumed. The additional buses that are needed to serve the extra demand are distributed equally between the two select PT lines.

What-If simulation scenarios	Baseline frequency (min)	New frequency (min)
Scenario with 20% PT shift	X50: 30 250: 12	X50: 12 250: 8
Scenario with 40% PT shift		X50: 8 250: 5
Scenario with 80% PT shift		X50: 4 250: 5

Table 6: Baseline and new bus frequencies for different simulation scenarios

3.5.3 Preliminary results of what-if scenarios simulations

Table 7 summarises some key statistics for the network of Manchester comparing the baseline scenario against three scenarios with different demand shift percentages to public transport as well as with optimised traffic control plans for the intersections relevant to the two examined public transport lines, respectively. The values in the parenthesis correspond to the results from the scenarios without optimised traffic control plans. The results indicate overall slight improvement of the network and public transport service performance in all three examined scenarios with demand shift to public transport and adjustment of the bus frequencies to serve the new demand. With respect to the results for the optimised scenarios, the highest improvement is observed for the scenario with 80% demand shift to public transport (of the car trips attracted by the centroids near the stadium). Nevertheless, the scenario with 20% demand shift indicates significant reduction of the average delays for buses in the network as well as reduction in the average bus travel times.

KPI	Baseline Event Day Scenario	20% Scenario with (without) optimisation	40% Scenario with (without) optimisation	80% Scenario with (without) optimisation
Average Delay time - All vehicles (sec/km)	103.19	+0.89% (-1%)	+3.44% (-4%)	-10.19% (-5%)
Average Delay time - Bus (sec/km)	99.21	-11.67% (-2%)	+3.88% (-9%)	-6.47% (-9%)
Average Density - All vehicles (veh/km)	18.91	+1.43% (-2%)	+6.50% (-5%)	-0.37% (-7%)
Mean queue - All vehicles (veh)	3148	+5% (-3%)	+13% (-8%)	+3% (-9%)
Average Travel time - All vehicles	187.07	0% (0%)	+2% (-2%)	6% (-3%)

KPI	Baseline Event Day Scenario	20% Scenario with (without) optimisation	40% Scenario with (without) optimisation	80% Scenario with (without) optimisation
(sec/km)				
Average Travel time - Bus (sec/km)	229.41	-6% (-2%)	0% (-6%)	-5% (-6%)
Average Harmonic Speed - All vehicles (km/h)	19.24	0% (0%)	0% (+2%)	+6% (+3)

Table 7: Network-wide key performance indicators for the baseline scenario and different demand shift scenarios with optimised traffic control plans for public transport prioritisation

Table 8 presents the percentage improvement, compared to the baseline scenario, of the average delays for both considered bus lines (X50, 250) after the optimisation of the traffic signal plans. The 20% and 80% demand shift scenarios indicate the highest improvements in terms of average delays.

Scenario	Average Delay for X50 and 250 lines (sec/km)
20% demand shift & optimised traffic control plans	-11.74%
40% demand shift & optimised traffic control plans	-8.67%
80% demand shift & optimised traffic control plans	-11.03%

Table 8: Improvement of average delay time (sec/km) for different demand shift scenarios with optimised traffic control plans compared to the baseline scenario

Figure 27- 28 illustrate the simulated average road section densities for the baseline scenario and for the scenario with 80% demand shift to the bus lines X50 and 250 with optimised traffic control for the respective intersections. Overall, the section densities are the same in both scenarios, however, slight improvement is observed in the area where the two bus lines operate (marked with a rectangle in Figure 28), which aligns with the reduction in the average delays for the specific bus lines, presented in the table above.

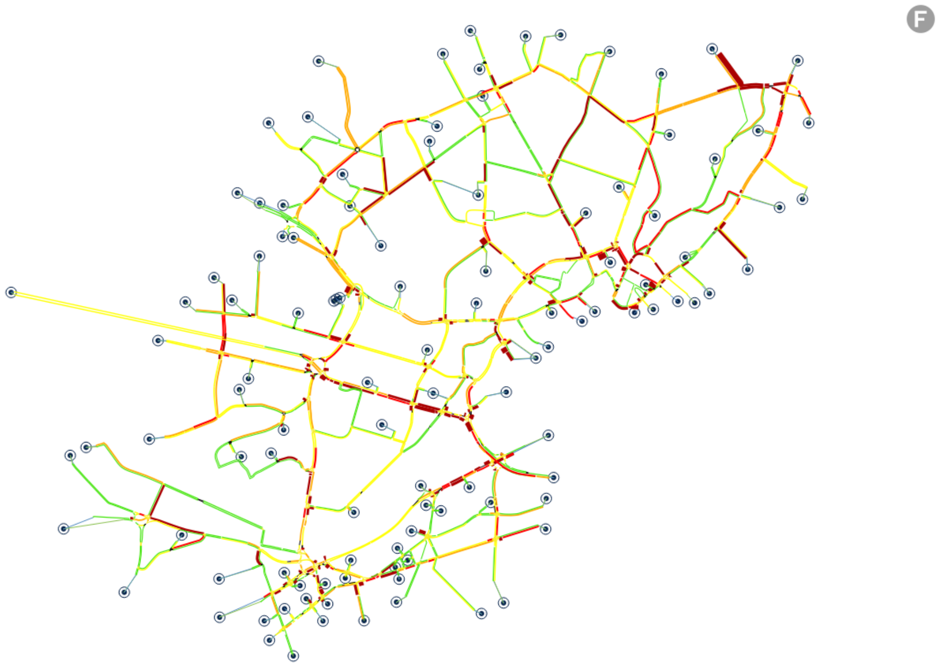

Figure 27: Simulated average section densities at the end of the baseline scenario

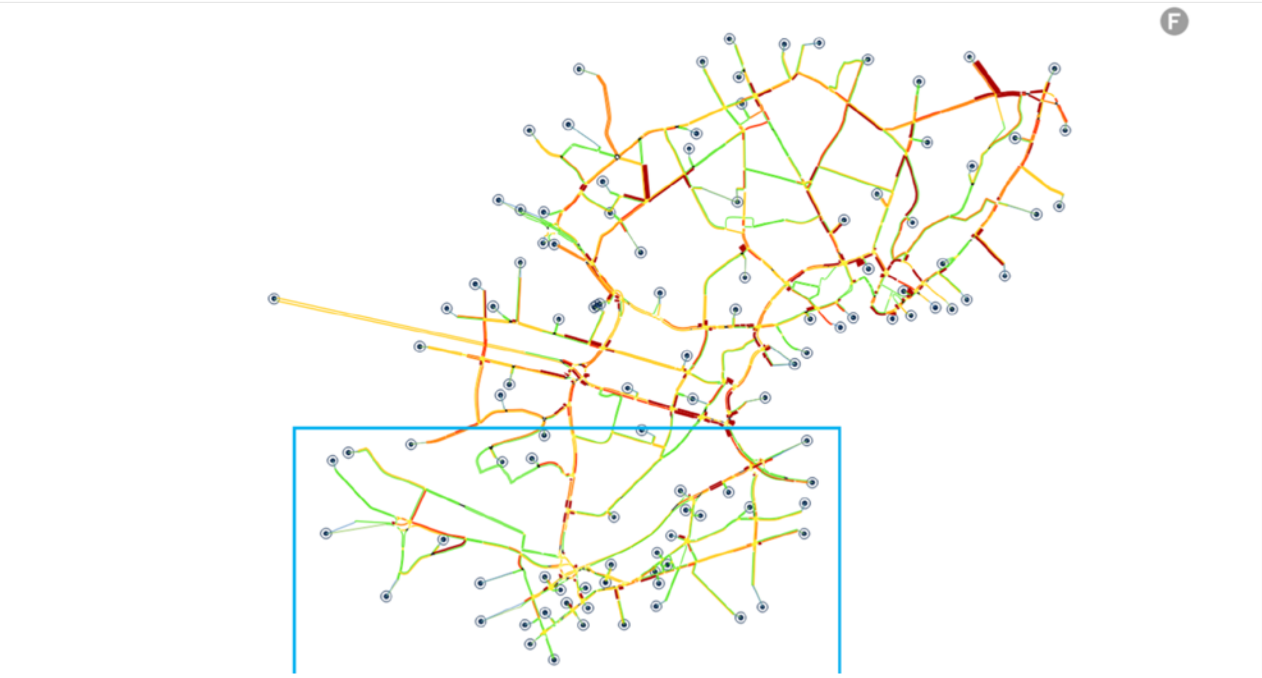

Figure 28: Simulated average section densities at the end of the scenario with 80% demand shift to public transport and optimised traffic control (the rectangle represents the area where the two selected bus lines operate)

3.6 Synchronization of Public transport and traffic control (WP5)

The objective of this module is to test and validate the effect of changing PT line frequency and corresponding signal timings for intersections of interest to facilitate improved traffic flow and emission conditions.

3.6.1 Methodology

Preparation Phase: Testing schematic and transport model finalisation

A document containing submodule testing specificities were shared with the stakeholder during the initial phase of the testing process. This document had consolidated fields for gathering information like simulation area, traffic node details, simulation scenario details and public transport line of interest. After getting the response from the stakeholder regarding the testing requirement specifications, the transport model is suitably adjusted and the testing process commenced. After the testing phase is complete a report is generated with the test result and will be sent to the case study stakeholders for their approval and further validation.

Step A: Testing Framework

The testing framework for this project focuses on an Aimsun model applied to the Greater Manchester area, featuring 26 public transport bus lines and 27 signalised nodes with over 60 signal phases. The model uses fixed traffic control plans to simulate and manage transportation during an event day scenario. By evaluating this complex network under the stress of increased demand, the system's efficiency in handling traffic and public transport adjustments is tested. The results from these event day simulations will be compared against a baseline scenario to measure improvements in traffic flow, bus operations, and overall system performance.

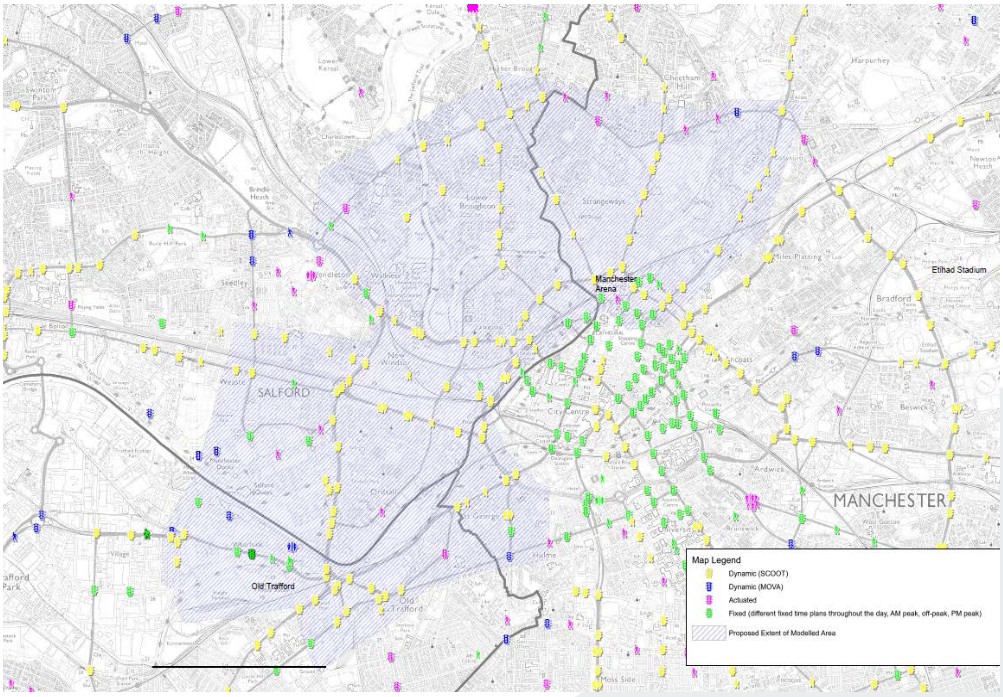

Figure 29: MAP view of simulation testing area in Greater Manchester

Optimization Phase:

In this phase based on the finalised transport model and stakeholder specified inputs we have executed the optimization process for predefined KPI specificity and after the optimization process concluded results were collected from the system for creation of report to be shared with the stakeholder and for further validation

Preparation phase:

- Meeting with Case Study leaders to discuss the need to adapt the case study definition if needed and define the experimental design.
- Drafting of a report with the case study definition and experimental design, to have the case study leader's approval.

Scenario simulation and result analysis:

- Preparation of the experimental framework
- Running of the optimizations/simulations
- Collection and analysis of the results
- Drafting of a report with the analysis of the results and main conclusions to be shared with Case Study leaders.

Feedback from Case Study Leaders:

- The case study leader reviews the report
- Meeting to discuss the consistency and appropriateness of the results
- Repeat the last two phases if needed.

3.6.2 Actions achieved and results

Step B: Test Results

The goal for the optimization process is to improve the congestion in the system along with the system wide emissions so in the baseline scenario the density was 28.33 veh/km where as in the optimised scenario it changed to 26.06 veh/km, for overall flow, in baseline scenario it was 21798 veh/h and in optimised scenario it increased to 24636 veh/h. Overall speed was 21.51 km/h in the baseline scenario and in optimised it became 21.06 km/h and the total distance travelled was 57763.04 km in the baseline scenario and in the optimised scenario it became 68049.29 km and travel time was 236.7sec/km in baseline whereas in the optimised scenario it became 235 sec/km.

After analysing the raw values of the underlying indicators, we can see that density decreased by 8.79% after optimization but traffic flow increased by 14.19%, indicatively this signifies better traffic conditions in the optimised scenario. The overall distance travelled improved by 19.35% w.r.t. Baseline scenario and the travel time decreased by -0.88% than the baseline which again depicts that the optimised scenario is less congested and much more efficient in traffic flow with respect to the baseline scenario for the event day simulation.

Figure 30 shows the pictorial depiction of the considered intersection for baseline vs optimised scenario comparison.

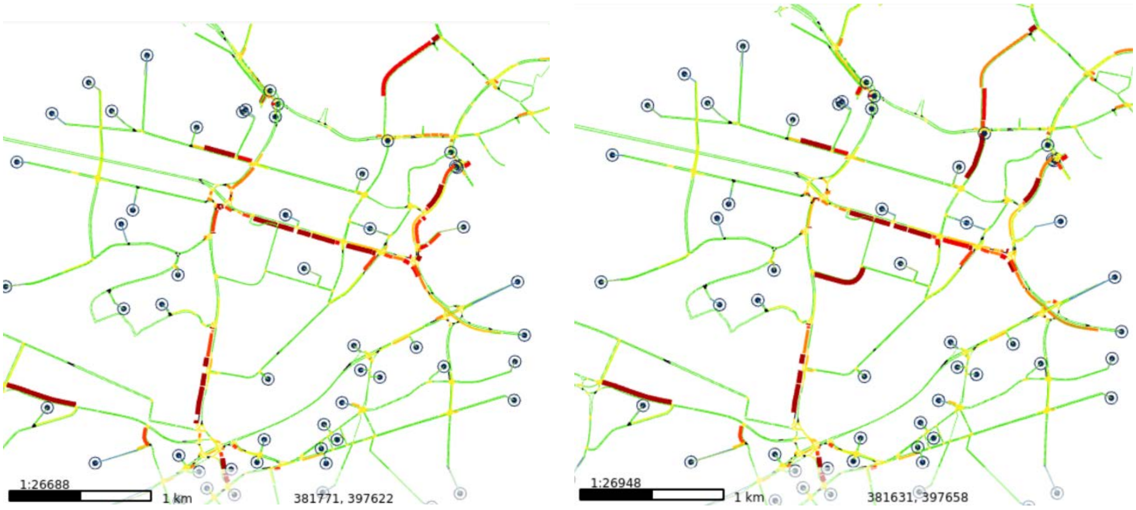

Figure 30: Density visual comparison for considered network area. Left: Baseline, Right: PuT + TC Optimisation

3.7 Dynamic Congestion Pricing Policy Optimization (WP5)

Dynamic Congestion Pricing (DCP) is a traffic management strategy where toll rates are adjusted in real time based on current traffic conditions. The primary goal of DCP is to discourage the use of private cars during peak congestion periods by imposing higher tolls, thus incentivizing drivers to either use public transport (PT) or travel during less congested times. By continually adjusting toll rates, DCP can help distribute traffic more evenly throughout the day, alleviating congestion in high-demand areas and times, and promoting a shift towards more sustainable transportation options like PT. In theory, DCP is an effective way to reduce private car usage and increase the reliance on public transport systems.

However, DCP faces several challenges. One major issue is that while it can reduce private car use, public transport systems may struggle to accommodate the increased demand, particularly during peak hours. Without sufficient coordination between DCP policies and public transport availability, passengers may face overcrowding, delays, or reduced service quality. Another problem is the lack of flexibility in reacting to sudden changes in demand or supply, such as unplanned events, road closures, or disruptions in PT services. Additionally, there can be equity concerns, as DCP might disproportionately affect lower-income drivers who are less able to absorb higher toll costs or shift to public transport.

The TANGENT approach efficiently implements Dynamic Congestion Pricing (DCP) by leveraging Computer Optimised Design (COD) to determine the optimal or near-optimal pricing policy in real time. COD uses advanced simulation and optimization techniques to evaluate traffic conditions and determine toll adjustments that will effectively balance demand between private car use and public transport (PT). By continuously analysing traffic data, TANGENT dynamically adjusts tolls based on current congestion levels, ensuring that toll rates are not only responsive but also strategically aligned with the overall traffic and public transport network.

The key performance indicators (KPIs) for optimising Dynamic Congestion Pricing (DCP) include the level of congestion both inside the DCP zone and in its surrounding areas, total revenue generated by the pricing policy, and the reduction of system-wide emissions. By monitoring and adjusting these KPIs, the DCP aims to balance traffic flow within and around the pricing zone, ensuring that congestion is not simply shifted to other areas. Additionally, the total revenue obtained from the pricing policy can be reinvested into public transport or infrastructure improvements, while emission reductions contribute to environmental sustainability and long-term urban mobility goals.

3.7.1 Methodology

Step A: Testing Framework

The Dynamic Congestion Pricing (DCP) testing framework for the Great Manchester area is designed to assess the effectiveness of toll adjustments in managing traffic flow during special events. Using the Aimsun traffic simulation model, this framework incorporates real-world traffic conditions of the area. The toll function is modelled using a sixth-degree polynomial, allowing for a flexible and highly responsive toll pricing system that adjusts dynamically based on current traffic conditions within the DCP zone.

On an event day, when traffic demand increases significantly, the framework tests the performance of the DCP by simulating various toll pricing scenarios and comparing them against a baseline where no DCP is applied. This approach evaluates how well the DCP can reduce congestion within the zone and its surrounding areas, control the flow of vehicles, and maintain system efficiency. The simulation also measures total revenue generated by the pricing policy and its impact on system-wide emissions. By comparing the results with the baseline scenario, this testing framework provides insights into the efficiency and environmental benefits of the DCP under real-time, event-driven traffic conditions in a highly congested urban area.

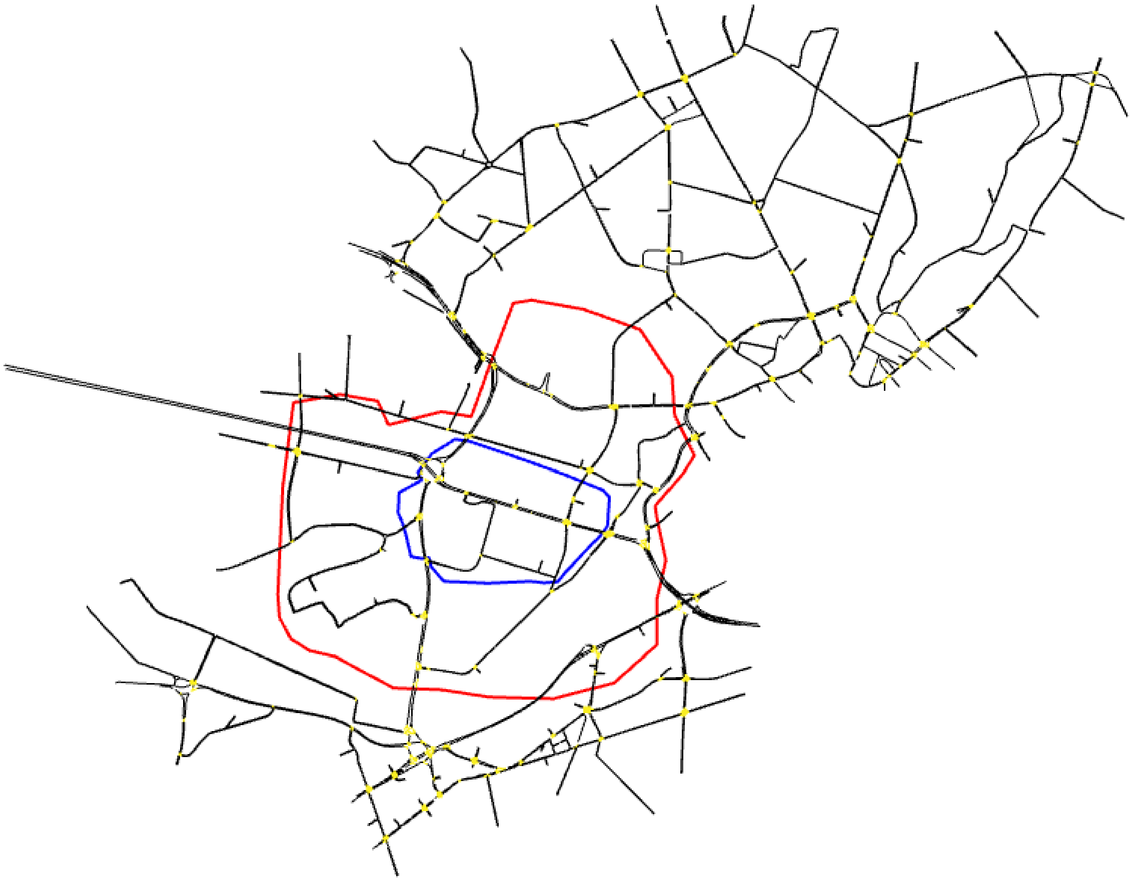

Figure 31: Area for DCP texting at Greater Manchester Area

Figure 31 shows the area for DCP policy testing, the area shown by the blue polygon the pricing zone and the area in the blue polygon is the immediate surroundings of the pricing zone.

3.7.2 Actions achieved and results

Step B: Test Results

After optimising the Dynamic Congestion Pricing (DCP) system, the results indicate significant improvements in various performance metrics. Within the pricing zone, congestion was reduced by 64%, demonstrating the effectiveness of the toll system in managing traffic flow and decreasing bottlenecks. Congestion outside the pricing zone also saw a 7% improvement, indicating that the pricing strategy not only benefited the immediate area but also helped to alleviate traffic in surrounding regions. Additionally, system-wide emissions were reduced by 56%, highlighting the environmental benefits of optimising traffic flow through DCP. In terms of financial performance, the DCP system successfully generated a profit of 260 Euros, showcasing its potential for both traffic and revenue management. These results collectively underscore the effectiveness of DCP optimization in improving urban mobility, reducing environmental impacts, and generating economic benefits.

Figure 32: Traffic Flow visual comparison for considered network area in baseline and optimized scenario

3.8 Consensus Mechanism (WP5)

The goal of Task 5.4, is to develop a comprehensive, automated decision-support tool designed to aid decision-making and foster consensus among stakeholders with divergent opinions. Drawing from actual stakeholder preferences and cooperation patterns obtained through structured surveys, our work, detailed in D5.4 proposes a framework that realistically models the key stages of the consensus-reaching process, until the reach of consensus between stakeholders.

For testing the modelling framework, the same four-step methodology described in section 2.2.1 used for testing the WP3 module, was followed. The adaptation of this methodology to the specificities of the consensus mechanism is outlined below:

3.8.1 Methodology

Step A: Testing sample collection

During the initial phase of testing, the stakeholder cooperation survey (SCS) was distributed to commuters from each case study city, including Manchester. The SCS questionnaire is included in the Annex of D5.4. To collect the necessary sample, each case study was asked to identify 3 stakeholders. Unlike WP3, case study contact persons directly provided the survey material to stakeholders and collected the completed questionnaires, which were then forwarded to NTUA.

Step B: Execution of the consensus mechanism

The consensus mechanism is applied and its output, in terms of consensual opinions regarding stakeholder priorities when a particular traffic management strategy is implemented, is communicated to participants.

Given that not all strategies are relevant to all stakeholders (since the entity they represent might not be involved in the decision-making process for one or more TMS), the opinions communicated were individualised and determined by their responses to the TBS in Step A. For example, the material communicated to the testers who responded that DRT-PT is relevant for their city and organisations, are provided below (Figure 33):

Section 3 of 5

DRT-PT

During the testing phase of the mechanism, we have engaged various stakeholders like you and determined that the collective opinion regarding the different network objectives for the DRT-PT (Synchronization of on-demand and transit modes) traffic management strategy is as follows:

Collective Stakeholder Preferences

Objective A is more important than Objective B					Objectives are Equal	Objective B is more important than Objective A				
Objective A	Strongly		Moderately				Moderately		Strongly	Objective B
Service performance	☐ 5	☐ 4	☐ 3	☐ 2	☐ 1	☐ 2	☑ 3	☐ 4	☐ 5	Network efficiency
Economic performance	☐ 5	☐ 4	☐ 3	☐ 2	☑ 1	☐ 2	☐ 3	☐ 4	☐ 5	Service performance
Service performance	☐ 5	☐ 4	☐ 3	☐ 2	☐ 1	☐ 2	☑ 3	☐ 4	☐ 5	Environment
Network efficiency	☐ 5	☑ 4	☐ 3	☐ 2	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	Economic performance
Environment	☐ 5	☐ 4	☐ 3	☐ 2	☐ 1	☐ 2	☐ 3	☑ 4	☐ 5	Network efficiency
Economic performance	☐ 5	☐ 4	☐ 3	☐ 2	☐ 1	☐ 2	☑ 3	☐ 4	☐ 5	Environment

Strategy Description

As a reminder, the objective of this traffic management strategy is the joint optimisation of the running route and the scheduling (departure times) of Responsive Feeder Transit and Responsive Collector Transit systems, to facilitate access and egress connection to public transit services (first/last mile problem).

Service performance: Total passengers served
Network efficiency: Passenger travel time
Economic performance: Operational costs of the DRT fleet
Environment: Emissions of DRT fleet

Figure 33: DRT-PT: Communication of opinion modelling results

Step C: Feedback Survey

As with the testing of WP3 modules, stakeholders were contacted again by NTUA to complete a follow up feedback survey to assess both the questionnaire and the results of the opinion modelling. The distribution of the survey occurred from 19/02/2024 to 28/02/2024. The complete feedback questionnaire is included in the Annex.

Step D: Reporting on the results

The feedback collected during the testing is presented in the "Results" section that follows. Some interim results have already been presented internally to the consortium during the WP7 bi-weekly meetings dedicated to subsystem testing and the consortium's monthly audio meetings.

3.8.2 Actions achieved and results

A total of 12 stakeholders from all case studies, including 3 from the Manchester case study, were contacted by case studies and NTUA. Six stakeholders responded to the feedback survey, and their responses are pooled together and analysed below.

Stakeholders found the questions of the survey to be rather straightforward and understandable (Figure 34).

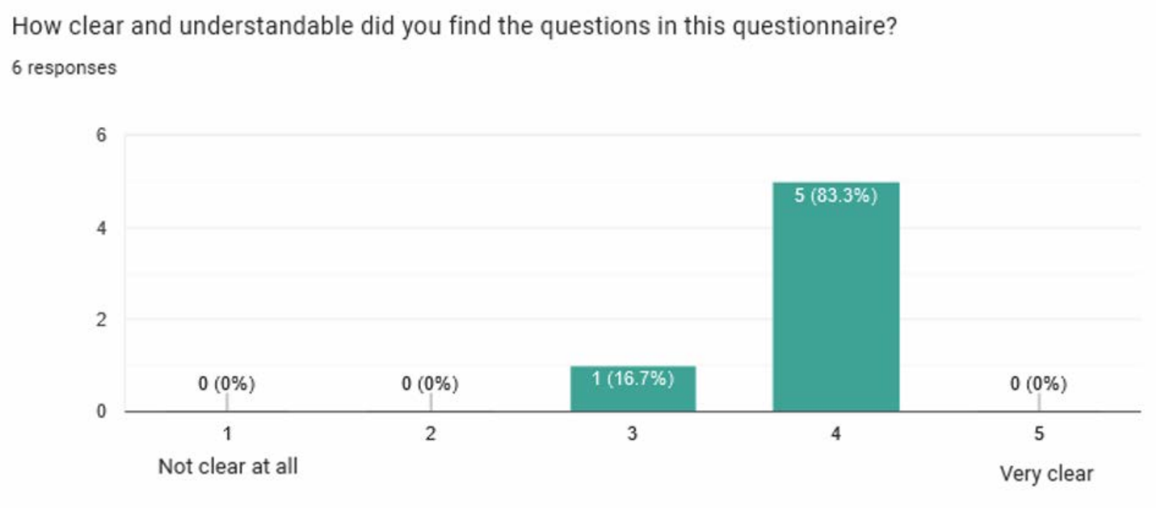

Figure 34: How clear and understandable did you find the questions in this questionnaire?

Perhaps unexpectedly then, 50% of respondents considered that a few questions appeared to be out of context (Figure 35). This issue is attributed to two factors: first, the survey elicited both stakeholder preferences and the institutional relationships between the entities they represent. Although related, these themes are distinct, which is uncommon in similar surveys that are highly focused. Additionally, the indicators used for eliciting relationships, such as the frequency of data exchanges between entities, do not directly reveal their relevance to the overall philosophy of the questionnaire.

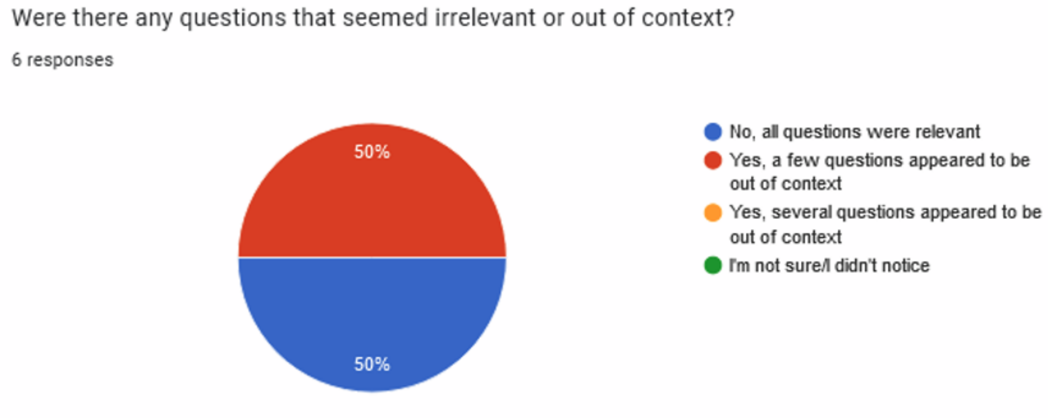

Figure 35: Were there any questions that seemed irrelevant or out of context?

Nevertheless, the instructions provided with the questionnaire were deemed adequate by participants (Figure 36).

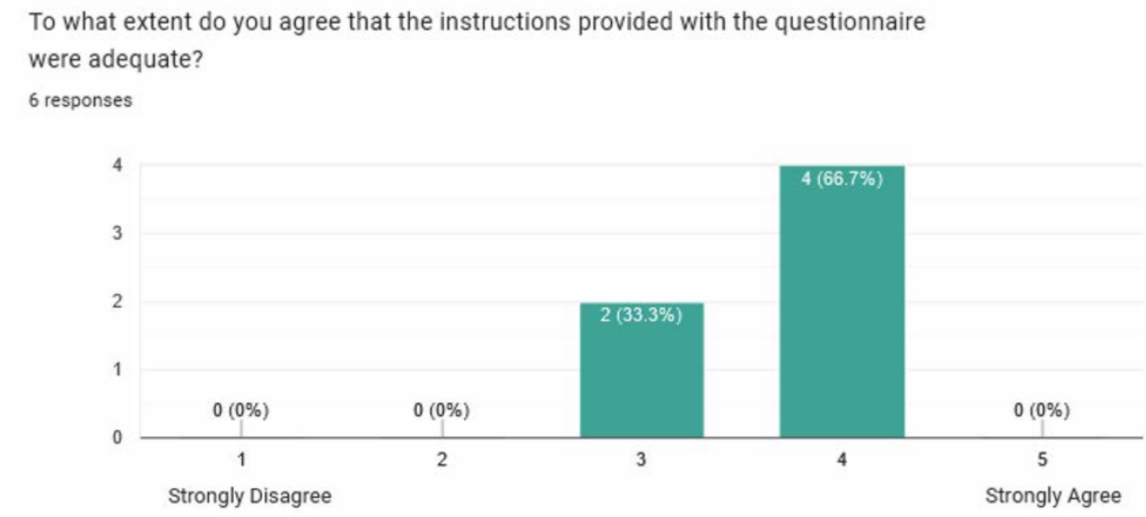

Figure 36: To what extent do you agree that the instructions provided with the questionnaire were adequate?

Opinions were more mixed regarding the overall formatting of the questionnaire. Unlike traditional question design (multiple-choice, open-ended, etc.), the need to provide institutional relationship information by filling a matrix in an Excel format (Figure 37) requires more cognitive effort and may not be immediately intuitive.

Stakeholder Category	Stakeholder Name	**B1**. Communication frequency	**B2.** Integration	**B3.** Data
Government & Authorities				
European Union				
Ministry of transport	Department for Transport	4. 1-2 times/year	2. Partnership: We work together as a formal team with specified responsibilities to achieve common program goals (note: responsibility for each organization is usually outlined in a Memorandum of Understanding or other agreement).	4. Degree 4 – Seamless sharing of information: Universal interpretation of information through data processing based on cooperating applications
Other national ministry				
Regional government				
Local authority				
Neighbouring city	Local councils surrounding Greater Manchester and those across (mainly) North of England	4. 1-2 times/year	3. Collaboration: We work side-by-side and actively pursue opportunities to work together as an informal team (i.e., do not establish a formal agreement; work together "in the spirit of collaboration").	1. Degree 1 – Unstructured data exchange: Exchange of human-interpretable unstructured data such as the text found in operational estimates, analyses and papers
Local transport authority				

Figure 37: Stakeholder relations matrix

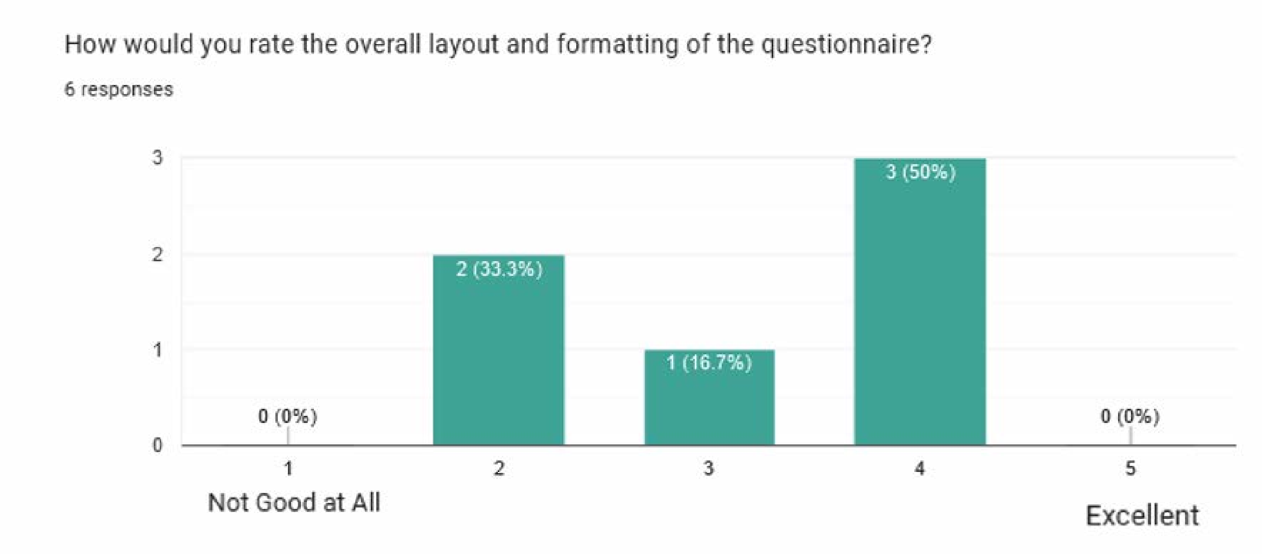

Figure 38: How would you rate the overall layout and formatting of the questionnaire?

The length of the questionnaire was also deemed excessive (Figure 39), with 67% of respondents finding it too long. This result was anticipated during internal test runs of the survey. The decision to proceed was based on the following: this survey targeted the few stakeholders knowledgeable about the decision-making, cooperation, and communication patterns among stakeholders involved in the transport network's management. For instance, the 14 questionnaires collected in the Stakeholder

Cooperation Survey contrast with the 1859 responses across the four case studies for the TBS, aimed at the general population. To compensate for the few respondents, we opted to demand more cognitive effort from participating stakeholders, facilitated by case study leaders who primarily distributed the questionnaire within their professional circles. Thus, the 14 questionnaires documented 248 cooperation instances and 46 opinion matrices, numbers suitable for the opinion modelling. This cognitive load was significant for some respondents, as noted by two respondents in open-ended questions on general comments or suggestions on the questionnaire content and format.

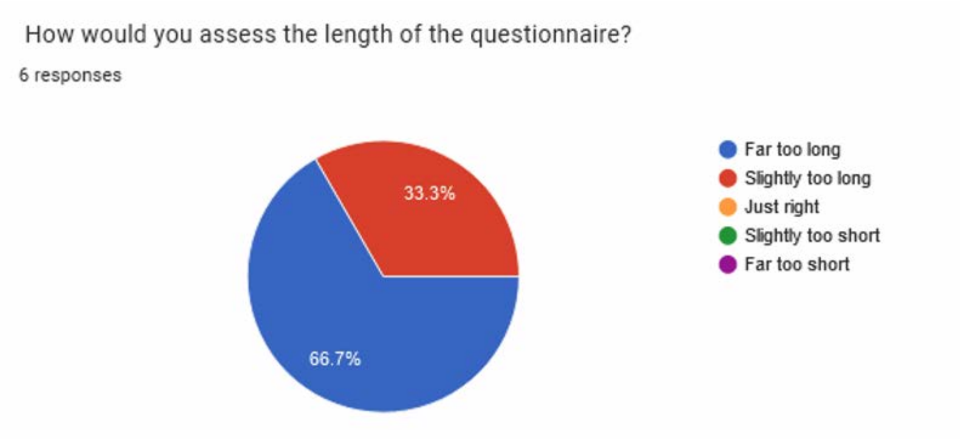

Figure 39: How would you assess the length of the questionnaire?

This cognitive load is also reflected in the fact that most (50%) participants completed the questionnaire in 25 to 30 minutes (Figure 40). For reference, the survey was initially timed at 25 minutes, a duration that most participants did not significantly exceed.

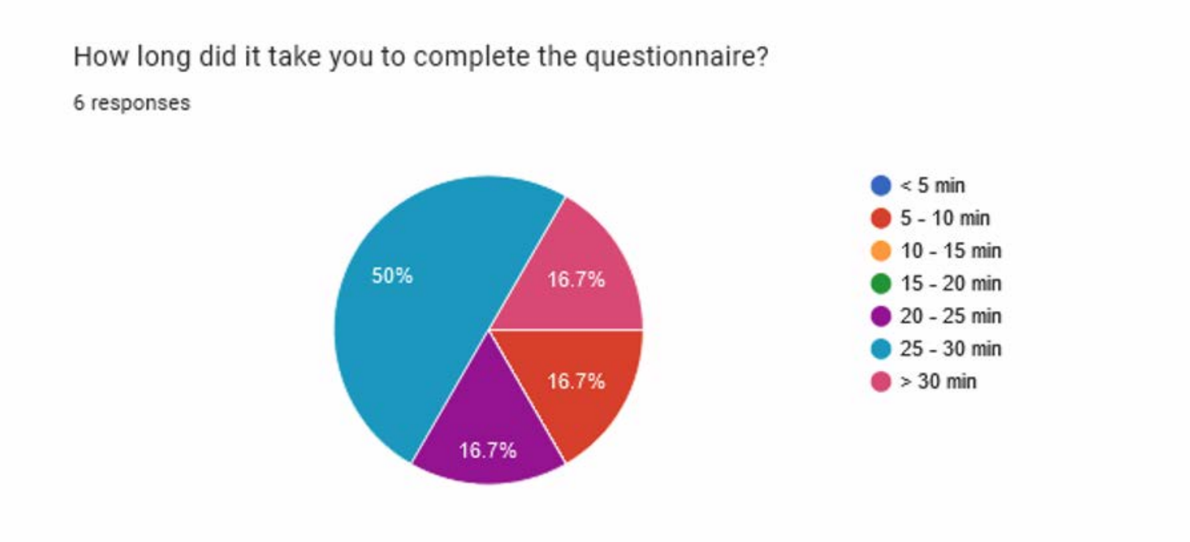

Figure 40: How long did it take you to complete the questionnaire?

Modelling insights

As discussed in D5.4, the opinion modification of the consensual preferences has two main objectives. First, the original opinions of the stakeholders must be preserved to the greatest extent possible, ensuring that each stakeholder's unique perspectives and insights are respected and incorporated into the decision-making process. Second, the consensual collective preference must be accepted by all stakeholders, as this sense of ownership enhances the legitimacy of the decision-making process and ensures that the policies (in this case, traffic management strategies) are more likely to be effectively implemented.

The consensus mechanism successfully achieves both objectives, as stakeholders have explicitly accepted the legitimacy of the consensual opinion (Figure 41) and feel that the consensual opinion is not significantly divergent from their own (Figure 42). This result serves as a robust indicator of the consensus mechanism's capacity to determine the true consensual opinion.

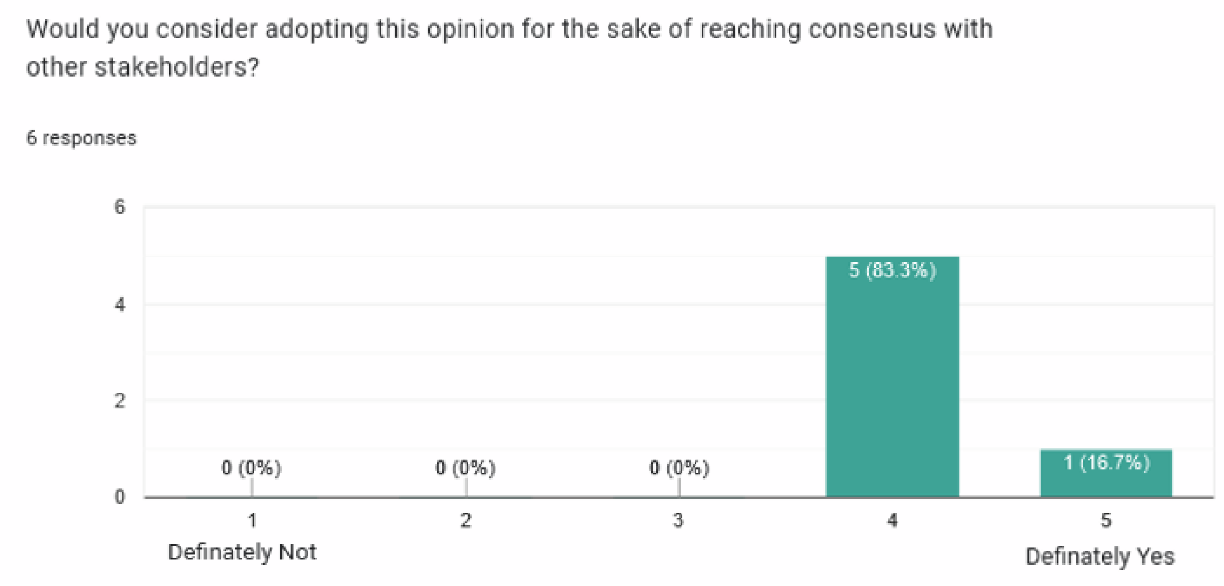

Figure 41: Would you consider adopting this opinion for the sake of reaching consensus with other stakeholders?

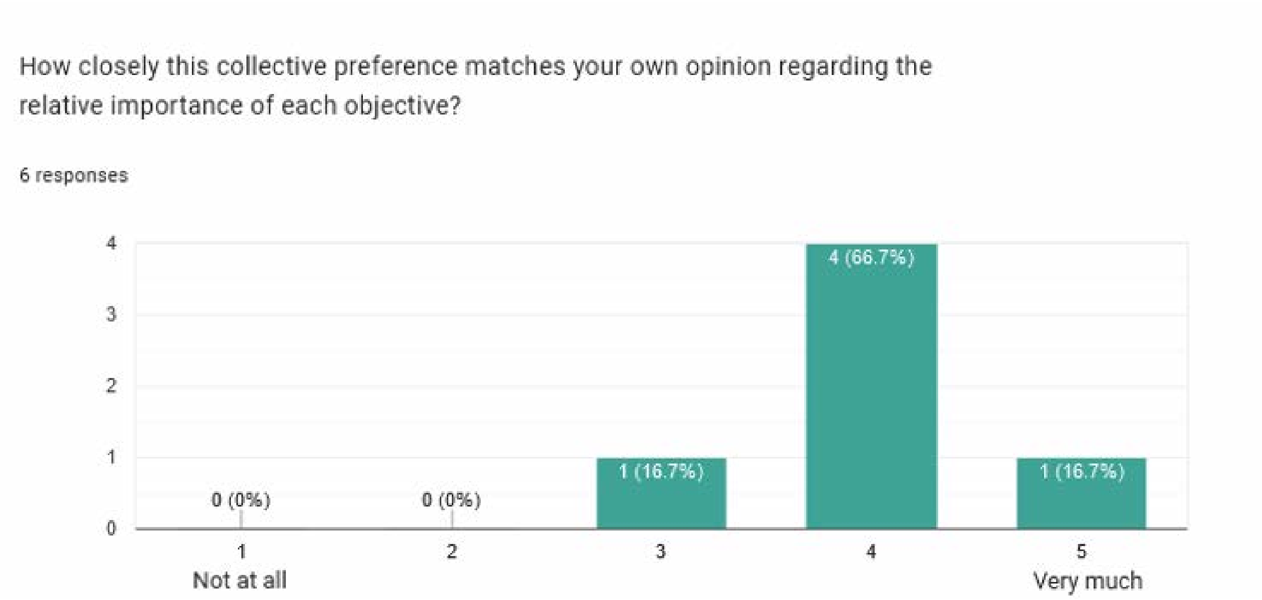

Figure 42: How long did it take you to complete the questionnaire?

Ultimately, stakeholders exhibit general trust in the consensus mechanism's operation, as depicted by the responses to the corresponding question (Figure 43).

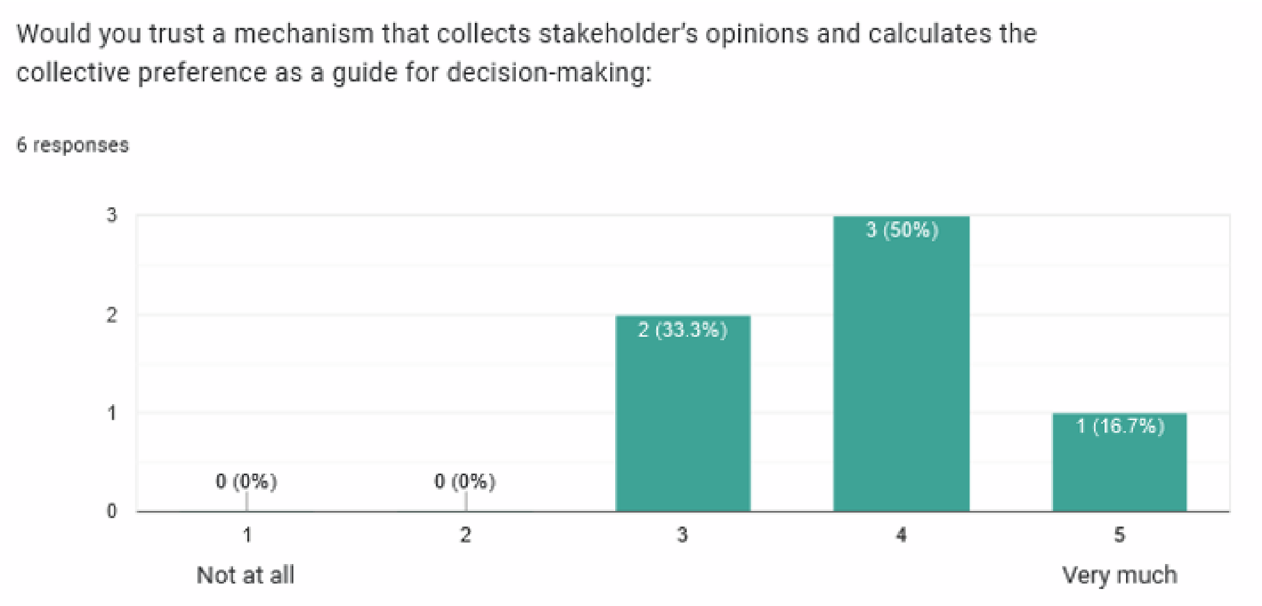

Figure 43: Would you trust a mechanism that collects stakeholder's opinions and calculates the collective preference as a guide for decision-making

4 Testing of the overall system

The testing activities of the overall system aim to assess the functionalities of the 3 services of the TANGENT tool. They are related to the WP7, more specifically to T7.3 “Upscaling and full operation: testing of the overall system”. The test phase of the overall system is divided in two subtasks:

- **"Subtask 7.3.1 Technical upscaling and full operation of TANGENT tools"**: Technical tests to assess the proper integration of the subsystems provided by the technical partners and developed under WP2, WP3, WP4 and WP5.
- **"Subtask 7.3.2 Non-technical testing and business models’ evaluation"**: Performance, usability, acceptability testing to be performed by the potential end-users of the tools: the case studies.

The test period is also framed by the WP6: Task 6.4 “Integration and development of TANGENT decision-making support tool for coordinated traffic and transport” (M16-M37) and deliverables D6.2 “TANGENT tool development and integration - 1st release” (M32) and D6.5 “TANGENT tool development and integration - 2nd release” (M37).

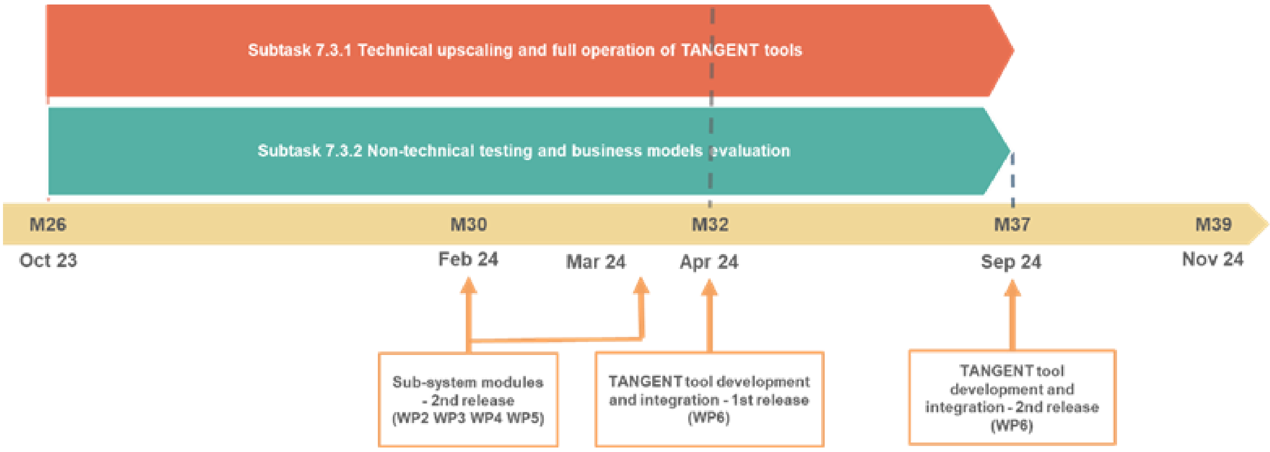

Figure 44: Timeline of WP7 testing activities

Figure 44 represents the global timeline of the testing of the overall system. The top section represents the execution of Subtask 7.3.1, where the technical testing of the overall tool’s integration has been done progressively, in strict collaboration between the WP6 leader and the technical partner responsible for the subsystem under integration. The bottom section represents the execution of Subtask 7.3.2.

During the first months of the project, TfGM, in collaboration with WP1 and WP7 partners, defined the Greater Manchester case study and the services to be implemented and tested under various scenarios, according to the city's challenges and interests. The said services and functionalities related to Greater Manchester case study are listed in the following table.

Service	Functionality	Scenario	Real-time or simulation/virtually
Service 1: Enhanced information service for multimodal transport management	Current state of the network	Daily Commuting Planned Events Unplanned Events	On-Site
	Future state of the network	Daily Commuting Planned Events Unplanned Events	On-site
Service 2: Real Time Traffic Management Services	Synchronization of Public Transport and Traffic Control	Daily Commuting Planned Events Unplanned Events	Virtually
	Informing the Transport Passengers (Dissemination Plan)	Daily Commuting Planned Events Unplanned Events	On-site
Service 3: Simulation of pre-defined scenarios	Simulation of the following scenarios: 1. Promotion of PT and DRT services for events/matchdays 2.Simulating higher penetration of connected vehicles	Daily Commuting Planned Events Unplanned Events	Virtually

Table 9: Services and functionalities related to Greater Manchester case study

The two T7.3 subtasks are closely linked, and are fully interconnected with WP6 work on subsystem integration (Task 6.4 “Integration and development of TANGENT decision-making support tool for coordinated traffic and transport management”). WP6 itself is dependent on the progress of technical partners in the development of the subsystems. Therefore, the non-technical testing of each functionality by the case studies could only start when its development and integration were completed. The tests were therefore sequential.

4.1 Methodology

4.1.1 Technical testing

The technical testing activities were tackled between the technical partners who developed the different subsystems and A-to-Be, responsible for the integration of the functionalities and the development of the TANGENT global tool.

Therefore, the technical tests have been performed in the scope of T6.4 “Integration and development of the TANGENT decision-making support tool for coordinated traffic and transport management”.

4.1.2 Non-technical testing

From April to September 2024, several tests have been run to assess the different functionalities added progressively on the TANGENT integrated tool. The goal was to continuously carry out the testing until the complete tool and all its functionalities were validated before the end of September 2024.

4.1.2.1 Launch of the non-technical testing phase

On March 13th 2024 (M31) during the TMC, the WP6 leader performed a live session launching the TANGENT Dashboard, which has been continuously running since. At this time, the platform featured the first functionality integrated: the current state of the network (Service 1). All partners requesting access were granted credentials to use the platform, according to their assigned role.

4.1.2.2 Implementation of the non-technical tests

When the technical partners finished developing a functionality adapted for the TANGENT tool specificities (following the deadlines mentioned in Figure 44), the WP6 integrated it on the Dashboard, and non-technical testing was initiated with the non-virtual case studies, organised in test phases called "Steps".

For instance, Step 1 was launched on April 3rd until April 29th, in order to test the functionality "Current state of the network" in Daily Commuting scenarios. After April 29th, the functionality remained active within the integrated tool until the end of the project, but the core of its testing was considered finished after that period. This methodology has been iterated for all functionalities, until all the services and functionalities were integrated and tested: the whole TANGENT tool was completely tested. In addition, the TANGENT tool has built-in feedback functionality, which has allowed users to provide comments and report issues, extending the testing window of each functionality to the entire usage period.

According to the functionality assessed, one of the two following types of format was used:

- A questionnaire sent to the partners and the local stakeholders that have access to the Dashboard
- A virtual meeting with the partners and the local stakeholders that have access to the Dashboard

For the cases, different questions were asked, and the participants needed to go to the TANGENT tool and perform some operations to evaluate various aspects of the platform and the functionality under test.

These tests aimed to assess 3 aspects of the Dashboard:

- **Usability and reliability**: Evaluate the user-friendliness and the clarity of the Dashboard and the functionality
- **Accuracy of the information**: Assess the correctness of the elements displayed, in a qualitative way
- **Compliance with initial requirements**: Review and update of the expectations listed in deliverable D7.2 before February 2023

The questions have been iterated for each step of the testing and adapted to the functionality under evaluation, with the support of the relevant technical partner when needed.

4.2 Tests results

The functionalities have been tested in different scenarios (daily commuting, large planned events and unplanned events). The Table 10 summarises the elements tested and their testing time slots, taking into consideration subsystem development and integration.

STEP	Service	Functionality	Scenario	Non-technical testing dates
1	Service 1	Current state of the network	Daily commuting	April 3 to April 29, 2024
2	Service 1	Future state forecasting[1]	Daily commuting	29th April to 15th of May, 2024
3	Service 2	SNLB: Informing the Transport Passenger[2]	Daily commuting	May 15 to September 2, 2024
4	Service 2/3	Planner features: Synchronisation of Traffic Control & Public Transport[2]	Daily commuting	October / November 2024
5	Service 3	Simulation of predefined scenarios[2]	What if scenarios	October / November 2024
6	ALL	ALL	ALL	October / November 2024

Table 10: Functionalities tested for GM case study

4.2.1 Step 1: Current state of the network

The first step of the testing aimed at assessing the dashboard of TANGENT and the first functionality of Service 1: **Current state of the network**, during daily commuting.

To this purpose, a questionnaire was sent to TfGM, using Google Forms. The questions can be found in Annex I.

As this was the first time the partners were asked to review some parts of the TANGENT tool, specific questions about some elements related to the Dashboard in general, not targeting the functionality assessed, were also asked.

Displayed below is a screenshot of the TfGM Dashboard, showing a user-customised view of the 'current state of the network', complete with maps, various datasets and widgets.

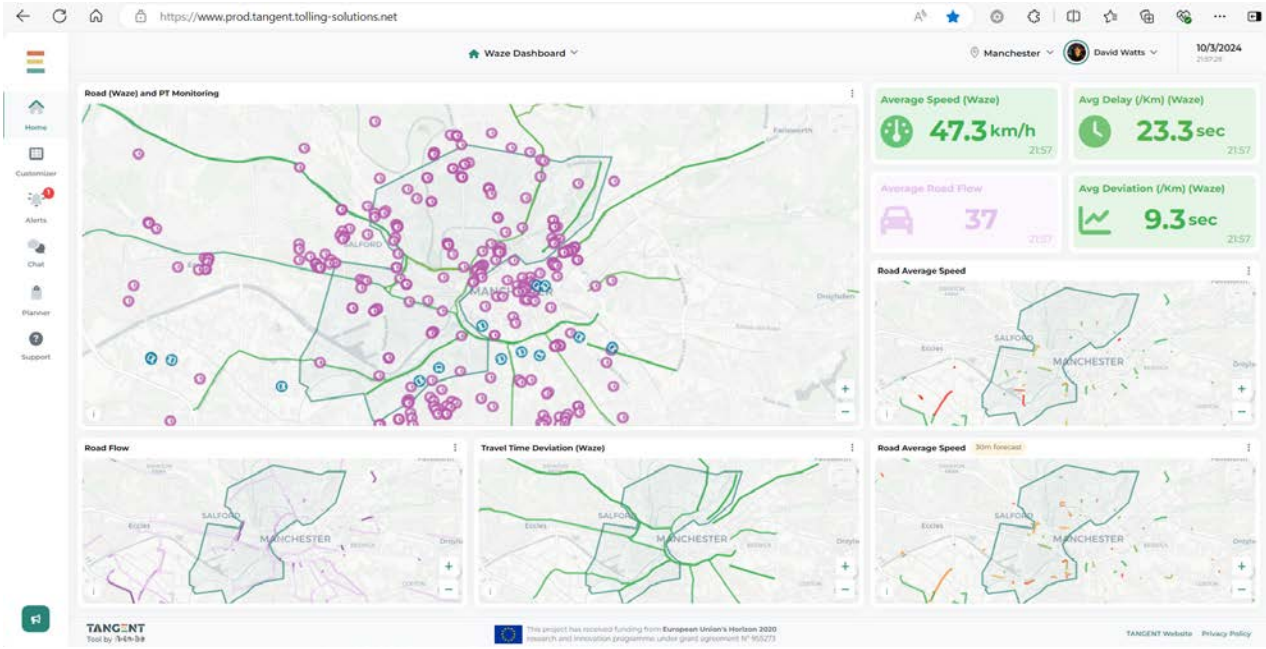

Figure 45: Greater Manchester dashboard

4.2.1.1 Respondents

For this functionality, four respondents from TfGM sent feedback using the questionnaire:

- 3 ITS engineers
- 1 Urban Traffic Control Engineer

4.2.1.2 Results

Usability and reliability

Half of the respondents think the main page has the right amount of information, the other half felt it has a fair bit too much information. 75 % of the respondents feel the information on live traffic and incidents is easy or very easy to understand, and 100% think the information on live public transport is easy or very easy to understand. For 75 % of the participants, the customizer is either easy or very easy to use.

Figure 46: Usability of the dashboard – 1

Some comments regarding the usability and the reliability of the dashboard were shared:

- About live data:
    - The meaning of the colours (e.g. average speed data) is unclear. Suggestion: rather than poly-lines, dots/blips at the point of recording might be a better way to illustrate this
    - The dashboard looks good - perhaps a layer checklist might also be useful
- About the customization:
    - It would be good to create specific dashboard layouts per user, per event, e.g. Old Trafford Matchday Dashboard, Concert Dashboard, Christmas Dashboard etc.
    - I like how easy it is without first going to a separate page first

On the general use of the tool, all of the respondents don't think the tool is unnecessarily complex, they all think it is easy or very easy to use. They all think that most people would learn to use this tool easily or very easily.

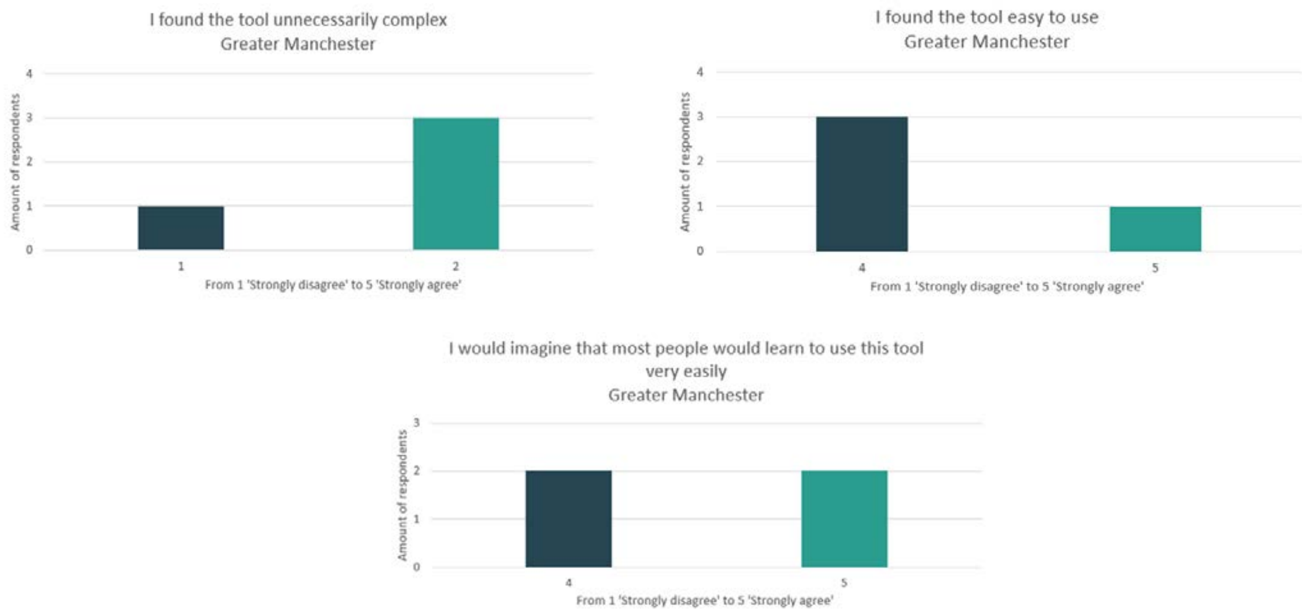

Figure 47: Usability of the dashboard– 2

Overall, the TfGM team thinks that the tool and its functionalities are easy-to-handle and understand, but the live data display could be improved. The developers of the tool need also to be careful to not put too much information on the dashboard. TfGM also recognised some of the limitations in the information that could be visualised, due to the types and granularity of the information available (e.g. length of the WAZE journey time links).

Accuracy of the information

Regarding the correctness of the elements displayed, a majority of the respondents think the KPI figures and the incident data displayed are only averagely coherent. However, a majority of the stakeholders thinks the traffic data displayed and the data displayed when elements are clicked on the maps are coherent.

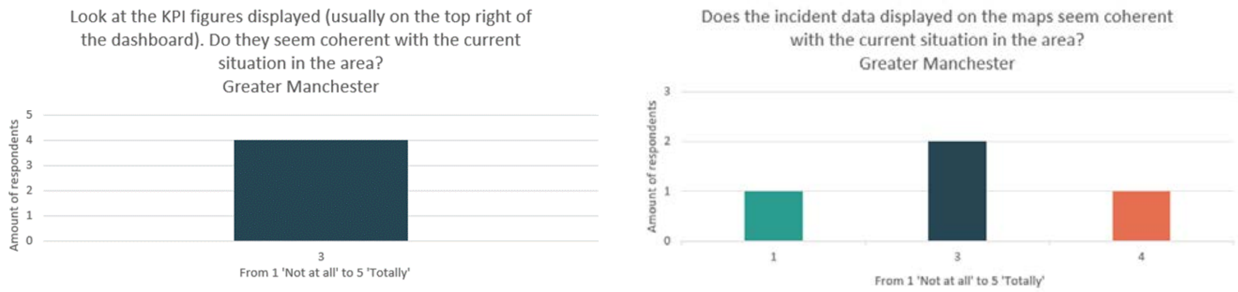

Figure 48: Correctness of the elements displayed - 1

The element that divides respondents' opinions is the public transport data displayed on the maps: each person has a different opinion, from not coherent at all to coherent.

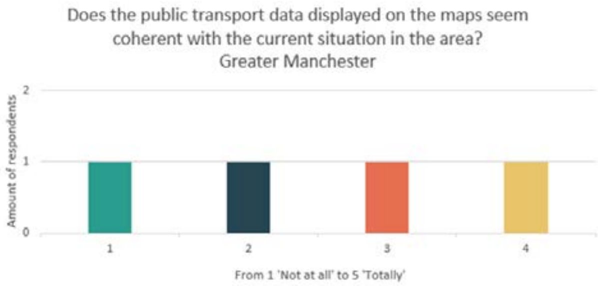

Figure 49: Correctness of the elements displayed – 2

Some comments were shared regarding the maps and figures:

- Some struggled to display incident data maps on the dashboard or in the customizer
- Very few public transport data is available - only a handful of bus routes for example

Compliance with initial requirements

To the question "Do you think the city data sources are well covered?", half of the respondents answered "Neutral", one considers they are well covered, one thinks they are not well covered.

For the Greater Manchester case study, TfGM initially defined 6 expectations regarding this functionality (current state of the network). The following feedback have been shared by the respondents of the survey:

Expectations	Not met	Partially met	Totally met
Expectation 1: Visualise (mapped view) the current network status		50 %	50 %
Expectation 2: Visualise congestion identified by journey times above stated 10 %		100 %	
Expectation 3: Visualise (mapped view) the current network status of public transport (buses and tram)		75 %	25 %
Expectation 4: Notification of the delay of the various services (buses, tram)	50 %	50 %	
Expectation 5: Visualise (mapped view) of incidents and events on the network	25 %	50 %	25 %
Expectation 6: Visualise (mapped view) planned events on the network (roadworks, lane closure)		50 %	50 %

Table 11: Assessment of the expectations of Greater Manchester for the functionality "Current state of the network"

Most expectations are partially or totally met, unless the Expectation 4: "Notification of the delay of the various services (buses, tram)", which is coherent, as this functionality only aims at monitoring traffic and public transport status, with only visualisation. This notification functionality will be possible at STEP 3 of the testing.

The expectation 5: “Visualise (mapped view) of incidents and events on the network” has partial results, as the tool did allow during this step to visualise the city events on the dashboard, only the incidents.

TfGM operational teams were also supported through this stage of the testing through online demonstrations of the Dashboard, provided by A-to-Be.

These sessions were performed over Microsoft Teams and enabled users to provide both verbal and visual feedback through live-use of the Dashboard. This enabled several changes and improvements to be made, such as the way in which traffic flow data was visualised, or the way in which bus direction was displayed.

These were well received and useful for staff, allowing them to ask direct questions to technical partners, enabling better understanding of the functionalities and system development.

Overall, the respondents are generally satisfied with the dashboard and the functionality tested; the main comment is that the tool would be enhanced by more data sources.

4.2.2 Step 2: Future state of the network

The step 2 of the testing aimed at assessing the second functionality of Service 1: **Future state of the network**, during daily commuting.

To this purpose, a questionnaire was sent to the non-virtual case studies, using Google Forms.

The below figure displays some of the forecasting mapping options, along with some of the widgets showing forecast road speed and road flow, on a custom dashboard. It should be noted that forecast data was only developed using the TFGM_CARS_05 dataset (real-time automatic traffic count sites that record speed and flow).

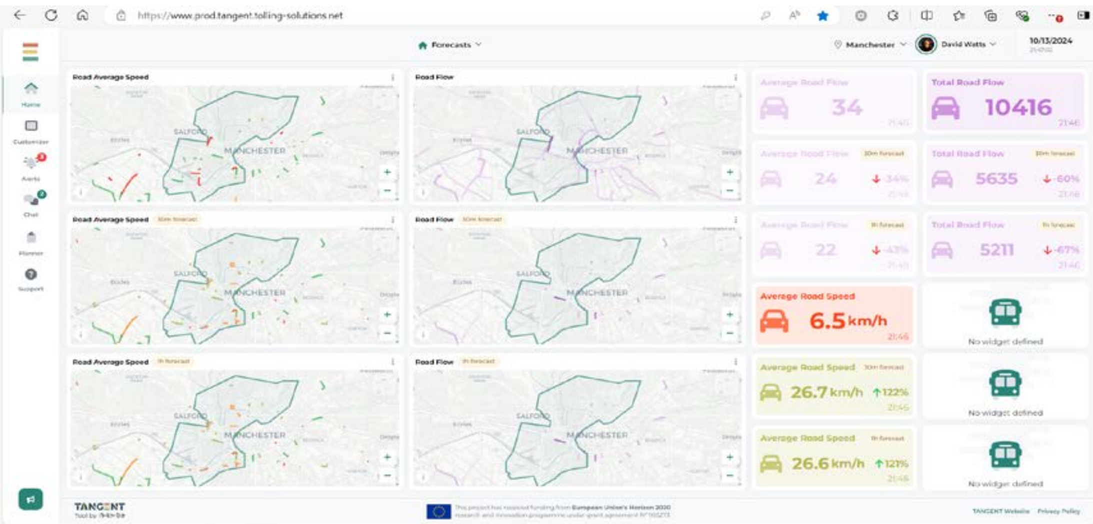

Figure 50: Greater Manchester dashboard for Future state of the network

4.2.2.1 Respondents

For this functionality, four respondents from TfGM sent their feedback using the questionnaire:

- 3 ITS / Urban Traffic Control engineers
- 1 ITS Development Manager

4.2.2.2 Results

Usability and reliability

Regarding the user experience of the functionality, 75 % of the respondents easily noticed the newly added forecast elements on the dashboard and easily compared them to the live elements. This type of display was totally expected by 75 % of the respondents.

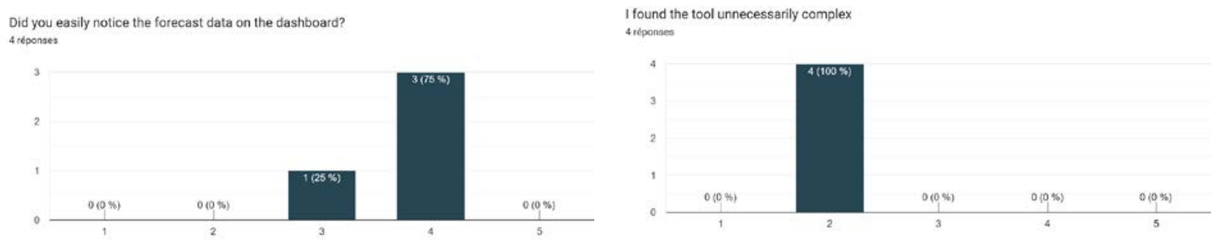

Figure 51: Usability of the forecast elements - 1

The KPI indicators are extremely clear (75 %) to identify the trend from live data to different forecast horizons, and the future evolution of the traffic. However, the maps are either easy to use (50 %) or not easy or difficult to use (50 %) to identify the trend from live data to different forecast horizons.

On the general use of the tool, all of the respondents think that the dashboard offers a better experience with the forecast, and that the tool is not complex to use. The tool is assessed as easy or very easy to use, and respondents think that most people would easily or very easily learn to use this tool.

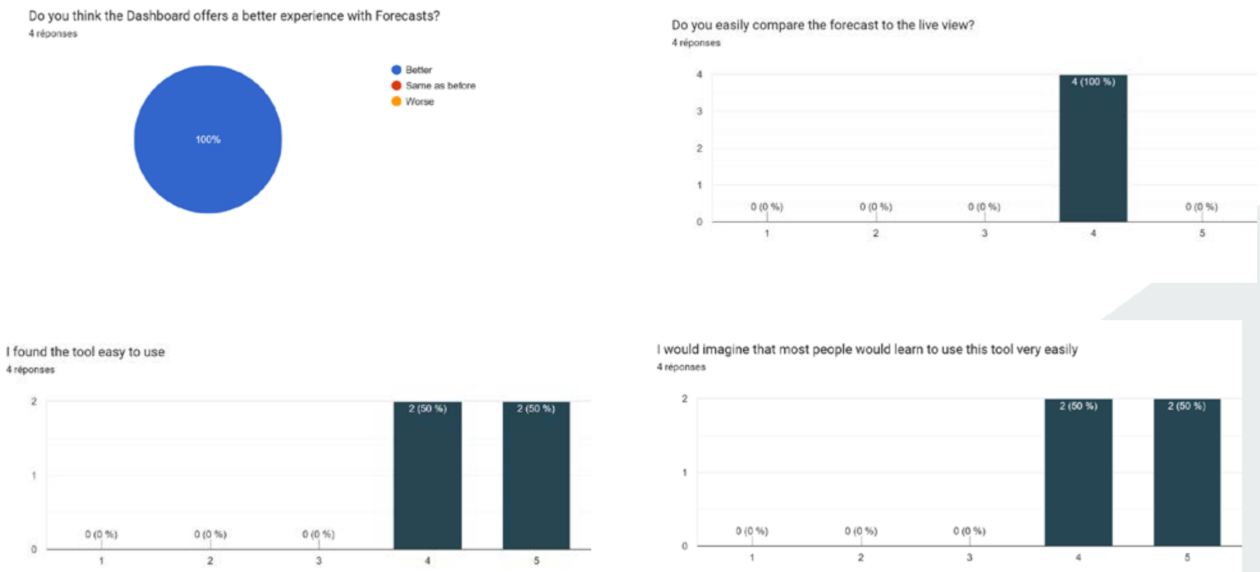

Figure 52: Usability of the forecast elements - 2

Accuracy of the information

Regarding the correctness of the elements displayed, at least 75 % of the respondents think the shorter-term forecast (15 or 30 minutes) for Road Average Speed and Traffic Flow is realistic or extremely realistic on the maps and the KPI indicators.

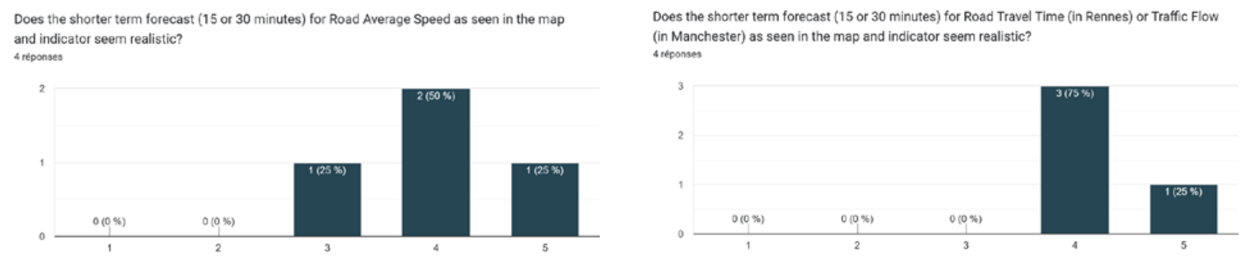

Figure 53: Accuracy of the forecast elements - 1

100 % of the respondents think the longer-term forecast (1h) for Road Average Speed and Traffic Flow is realistic on the maps and the KPI indicators.

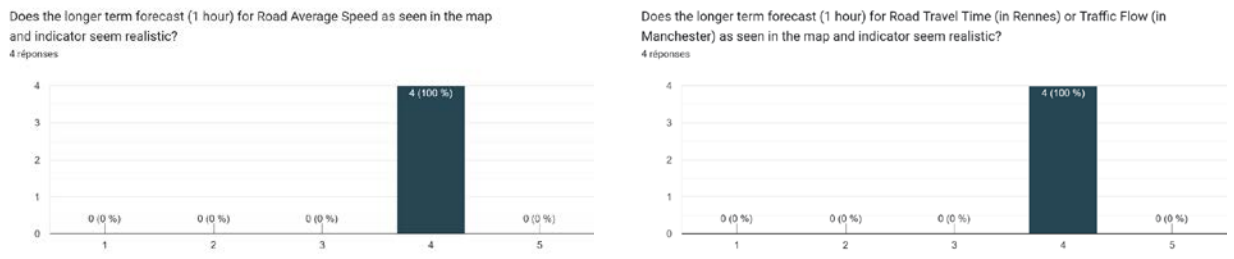

Figure 54: Accuracy of the forecast elements - 2

The suggestions or issues mentioned are the following:

- Provide an option to choose the duration of forecast, not just limited to 30m and 1 hour.
- Wider coverage would be more useful, but this is a TfGM data gaps issue
- Utilise WAZE journey time links as part of forecasting functionality.

Compliance with initial requirements

To the question “Do you think the city data sources are well covered?”, half of the respondents answered “Neutral”, one considers they are well covered, one thinks they are extremely well covered.

For the Greater Manchester case study, TfGM initially defined 2 expectations regarding this functionality (future state of the network). The following feedback have been shared by the respondents of the survey:

Expectations	Not met	Partially met	Totally met
Expectation 1: Visualise (mapped view) the prediction of the future traffic state in a range of 15 minutes and 30 minutes		50 %	50 %
Expectation 2: Display the predicted congestion hotspots and identify the impacts for the car users.		75 %	25 %

Table 12: Assessment of the expectations of GM for the functionality "Future state of the network"

The first expectation is not totally met; as mentioned in one comment, one possibility would be to choose the range of prediction. The expectation 2 is also partially met, as it is possible to see the future state of the network, with the same colour code used for the 1st functionality; therefore, it is possible to deduce the congestion hotspots.

Overall, the TfGM team is satisfied with the functionality “Future state of the network”, even though some elements could be improved, such as the prediction range, and ***arranging*** the display of the maps.

4.2.3 Step 3: SNLB: Informing the transport passengers

Step 3 of the testing aimed at assessing one of the functionalities of Service 2: **SNLB - Informing the Transport Passengers**.

Once integrated in the dashboard, the objective of this functionality is to allow the transport/traffic managers to create dissemination plans that can be activated by a list of designated profiles. Once a dissemination plan is activated, it triggers when the previously defined triggering conditions are reached and displays the parameterized message and real-time data on the chosen dashboard, to the chosen profiles.

Displayed below is the dissemination plan created as part of the testing for this functionality. This plan focussed on notifying selected users once the speed threshold has been met for a selected strategic route for Old Trafford match days (less than 25km an hour for a section of the A56 road).

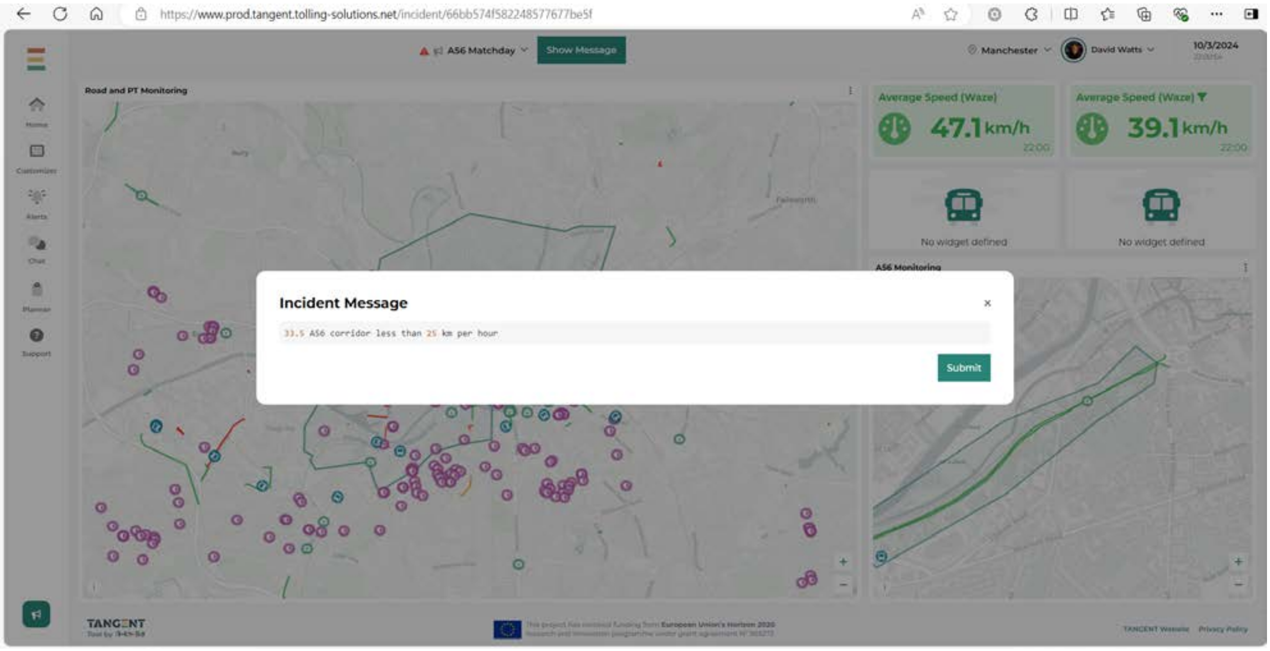

Figure 55: GM dashboard of the functionality SNLB - Informing the transport passenger

The functionality and the steps of the dissemination plan creation are further described in D6.5.

The assessment of this functionality was performed through an online meeting with the following partners: TfGM, A-to-Be and ID4MOBILITY.

Greater Manchester was the third case study to assess this functionality, after Rennes and Lisbon.

Feedback from TfGM:

- Interest in the functionality:
  - Sending obvious alerts that won't be missed by the operators
  - Highlighting incidents with high delays in deviations or during special events
  - Similar to functionality used by operational teams in existing and previously used systems.
- Propositions of evolutions:
  - Filter the triggers to a particular area to highlight incidents at local scale
  - Share notifications with other stakeholders and on social media to inform the transport passengers
  - Having other means of selecting specific localised routes or areas rather than the polygon tool only (e.g. selecting from list, clicking on map etc.)
- Difficulties / Questions:
  - When looking at a single dissemination plan, it would be useful for users to be able to select journey time links in a singular direction (e.g. southbound only), rather than both directions. It was unclear if the polygon tool enabled this.
  - Could dissemination plans be sent to a single named user only, as opposed to the whole user 'group'/authority?

The feedback from TfGM gives elements to iterate and improve the functionality in order to match the needs and challenges of the use cases. As Greater Manchester was the last case study to test this functionality, the possible evolutions then were listed to prepare the new developments for updating this functionality.

Common section to D7.3, D7.4, D7.5 (the non-virtual case studies deliverables)

The three meetings with each case study to test this functionality were extremely useful to highlight common improvements to implement on the Dashboard, in order to improve SNLB - Informing the Transport Passengers. The following elements were implemented:

- The trigger conditions can be defined using any indicator widget. This allows the use of Forecasts and filtered data as triggering conditions too.
- It is possible to add more than one triggering conditions and define the parameters of these several conditions: conjunction (“and”) or disjunction (“or”)
- Geographic filtering is now available on the Customizer, in order to create a Dashboard with maps and indicators focused on some specific geographic areas. It can then be used for this functionality: the user can parameter a dashboard on a specific area and choose it when creating a dissemination plan
- Data filtering: in the same way as the geographic filtering, when creating a new map or a new indicator in the Customizer, the user can select the data he is interested in visualising
- The messages of the dissemination plan are published in an AMQP Exchange, allowing integration with other systems for further distribution

End of the common section

A new session was organised with TfGM to test the updated functionality. The final feedback on TfGM regarding the dissemination plan is the following:

The testing and demonstration of Step 3 functionality within the TANGENT dashboard showcased traffic management could be enhanced in Greater Manchester. This feature allows operators to create custom action plans based on specific triggering conditions, such as journey speeds from Waze data or vehicle flow on key routes. These plans can notify operators when to focus on a particular area, route, or event, prompting timely and targeted interventions.

One key advantage of this functionality is its ability to predefine response strategies for common scenarios, which could be stored in a library of action plans. This would significantly reduce the time needed to react to disruptions, as operators can quickly reference or initiate pre-set responses for incidents like road congestion or public transport delays. The testing also highlighted the benefit of integrating these custom plans with simulation tools, allowing operators to test and refine action plans before they are applied in real-world situations.

The simulation capabilities add an extra layer of assurance by ensuring each plan is validated for its effectiveness in managing different scenarios. This could help optimise network performance by proactively managing traffic flow, responding to incidents, and adjusting public transport routes.

However, it became clear that the success of this feature relies heavily on the accuracy of real-time data from sources like Waze, and ensuring this data remains consistently reliable will be crucial. Overall, the updated functionalities hold significant potential to streamline traffic management and enhance operational efficiency.

4.2.4 Step 4: CIM: Synchronisation of Public Transport and Traffic Control

Due to a higher-than-expected technical complexity of the module developed in WP5, required by the functionality Synchronisation of Public Transport and Traffic Control, its testing can only be reported by mid-November 2024

4.2.5 Step 5: Simulation of predefined scenarios

Due to a higher-than-expected technical complexity of the module developed in WP5, required by the functionality What-if simulations, testing was completed for the first set of what-if scenarios can only be reported by mid-November 2024.

However, some tests have been performed by AIMSUN, in collaboration with Greater Manchester case study, as presented in section 3.5 “Transport model building for simulation-based analysis”.

4.2.6 Testing the TANGENT functionalities under different scenarios

As outlined previously, the goal of the TANGENT tool is to support operational and strategic stakeholders in managing traffic and operations across varying conditions, aiding them in addressing typical traffic situations as well as planned and unforeseen events that impact network efficiency.

In the TfGM case study, the following functionalities tested across all scenarios:

- Service 1: **Current state of the network**
- Service 1: **Future state of the network**
- Service 2: **SNLB: Informing transport passenger**

This section provides a high-level overview of how users adapted and tested the Dashboard for the scenarios through the non-technical testing.

4.2.6.1 Daily Commuting

Using the TANGENT tool for "Current State of the Network" (Service 1) allowed TfGM teams to observe Manchester’s traffic patterns and the impact on congestion during the AM and PM peak periods. As shown in the screenshot, Waze data highlights high levels of delay and expected deviations across the highway network during the AM peak, providing real-time insights into current traffic conditions, alongside other key information, such as the real-time location of bus services and roadworks. This provided more context and insight to operators without the need to change systems.

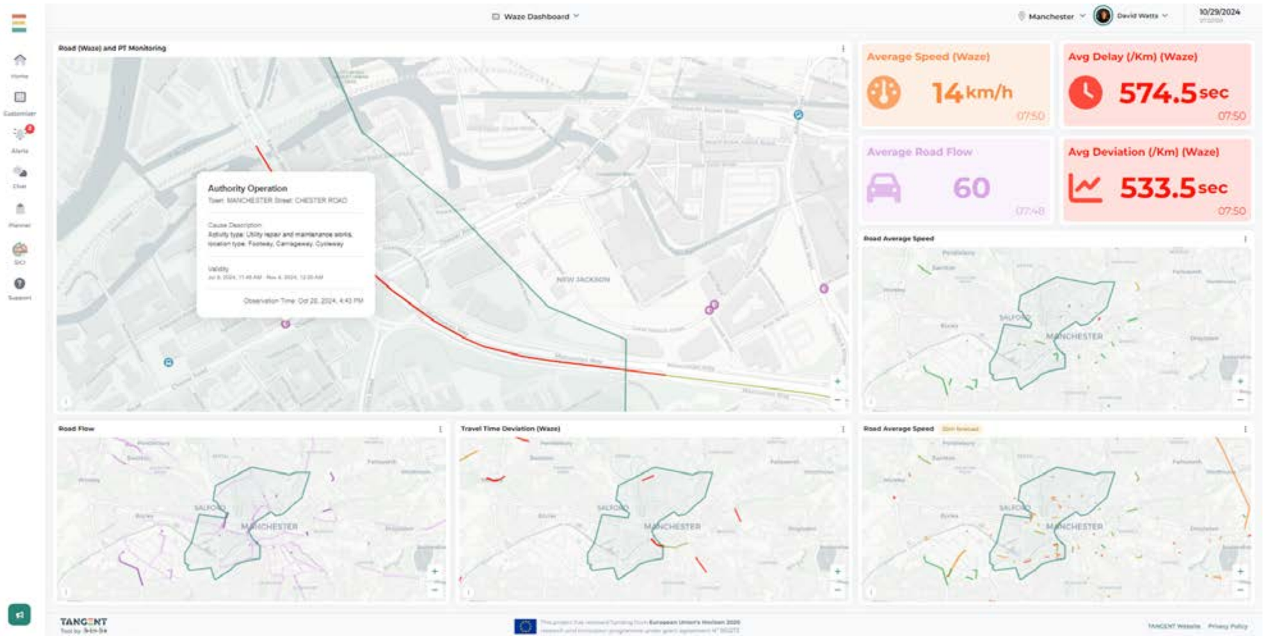

Figure 56: Example of the widgets on the Dashboard displaying high levels of delay and deviation during the AM peak period

4.2.6.2 Planned Events

The TfGM case study focused on monitoring areas near key event venues, specifically AO Arena and Old Trafford, where large concerts and football matches regularly impact not only local traffic, but the wider network. Using the TANGENT dashboard's "Current State of the Network" feature, TfGM could observe and monitor traffic flow and congestion levels surrounding these locations during events. The tool enabled real-time visibility into traffic conditions, allowing transport managers to anticipate and manage the effects of increased congestion. Additionally, with the "Future State of the Network" predictions, the dashboard provided estimates on expected flow and speed for user-defined areas, helping TfGM to anticipate future demand and manage this accordingly.

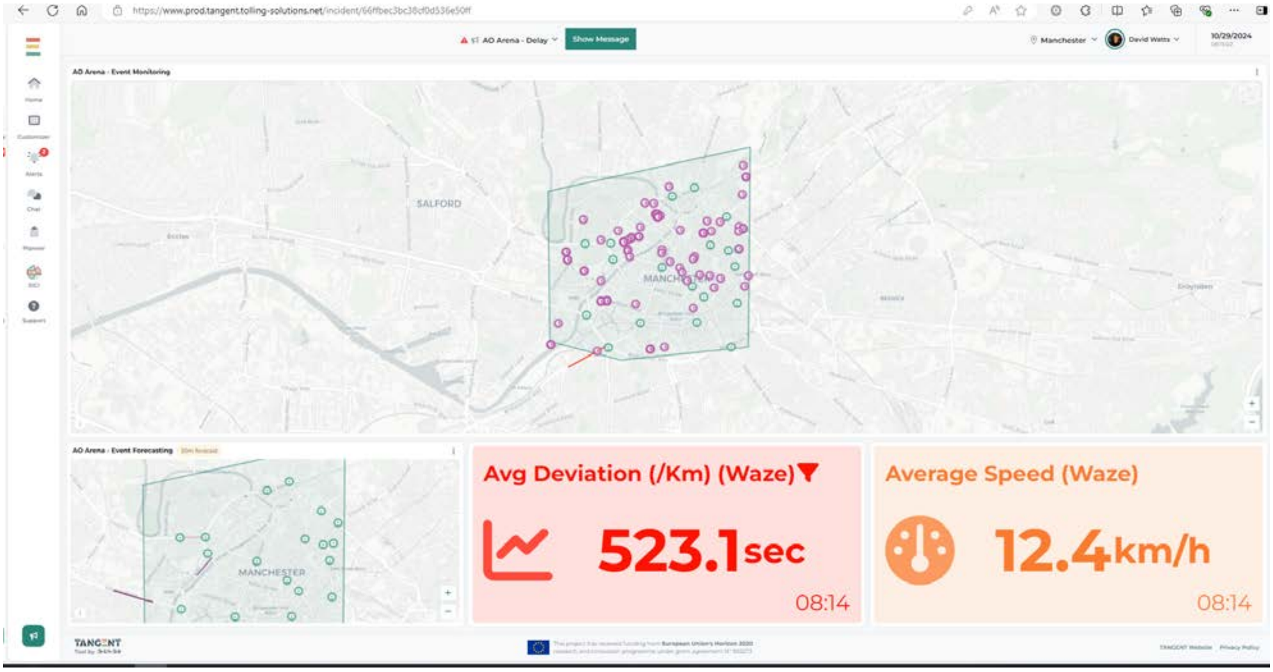

Figure 57: Example of the bespoke 'AO Arena' Dashboard, tested by operators during arena events

4.2.6.3 Unplanned Events

During non-technical testing for the TfGM case study in the TANGENT project, several unplanned incidents were detected, including roadworks that resulted in heavy congestion. One significant unplanned event captured in the Greater Manchester area involved temporary closures and traffic disruptions due to emergency roadworks, which created delays on key routes and bus services. The dashboard's real-time monitoring capabilities allowed for detection of these incidents, providing operational teams with the insights to respond effectively. Additionally, the TANGENT tool enabled a clearer view of congestion patterns as they developed.

5 Lessons learned and next steps

5.1 The lessons learned for Greater Manchester case study

5.1.1 Multi-actor collaboration on traffic management

Utilising the TANGENT dashboard has helped TfGM further understanding of the importance of multi-actor collaboration in traffic management. Given the existing experience of managing a complex network involving multiple stakeholders, such as local councils, transport operators, and private companies, TfGM already appreciates the need for coordinated efforts. However, the dashboard's integration of real-time data from different sources (e.g. Waze, public transport data, and vehicle flow) provides a single operational picture, facilitating more streamlined decision-making across stakeholders.

The dissemination plan functionality further highlights the benefits of collaboration by allowing stakeholders to access and respond to predefined action plans for specific scenarios. This would enable TfGM to initiate coordinated responses to incidents, making collaboration more efficient and proactive. A dashboard such as the one developed through TANGENT, with enhanced data sources would not only enhance TfGM's ability to manage real-time network performance but also demonstrate the operational value of shared data and information across different actors.

5.1.1.1 Lessons Learned

Effective traffic management in a growing city like Greater Manchester requires robust collaboration between various stakeholders, including public transport operators, local authorities, and private companies. A challenge has been aligning the priorities of different stakeholders, such as private bus operators, which previously made coordination difficult. However, as the region transitions to an integrated transport system through bus franchising and the Bee Network, this should simplify collaboration and give TfGM more autonomy over decision making.

5.1.1.2 Opportunities

TANGENT services enable better coordination through shared data and real-time insights, helping operational teams respond faster to incidents and disruptions. Bus Franchising, bringing bus services under local control, offers an opportunity to align services more effectively with the broader network, including other modes.

5.1.2 Data sharing / availability / reliability

5.1.2.1 Lessons Learned

Data integration across modes (e.g., trams, buses, roads) is a challenge due to varying systems, standards, and the quality of available data, however TfGM’s access to multiple data sources like WAZE, real-time automatic traffic count data and national access points such as live bus data has improved visibility and has emphasised the value of collecting and owning data sets across the network. This also reduced the requirement for legal agreements, such as NDAs to be signed as part of the data sharing agreement.

5.1.2.2 Opportunities

Having access to more comprehensive data would directly improve operational capabilities by feeding richer, real-time insights into the TANGENT dashboard, allowing teams to react more quickly and accurately to network issues. A broader data set would also enhance predictive tools, allowing operators to foresee potential disruptions more effectively. Additionally, a comprehensive and interactive data catalogue would be highly beneficial, as it would allow stakeholders to access and visualise different data streams in one place. This would also facilitate the seamless integration of new data sources over time, keeping the system adaptable and ready for future developments and integrations.

5.1.3 Functionalities of TANGENT

5.1.3.1 "Current State of the Network"

Real-time data dashboards developed through TANGENT were well received by TfGM's Control Centre, offering useful insights into the status of different modes of transport. This aids in managing congestion, identifying delays, and responding more efficiently. Though also currently being explored and developed through other workstreams, TANGENT demonstrated some of the key features and technologies such as the integration of WAZE data, bespoke user-configurable displays and predictive capabilities.

5.1.3.2 "Future State of the Network"

TANGENT's predictive capabilities provided TfGM with insight to foresee the impact of events (e.g., road closures, football matches), enabling proactive interventions. Though used in a limited capacity and though data was limited, it was beneficial to see how this feature could significantly improve planning and optimise network performance, particularly during large events or unplanned incidents.

5.1.3.3 "Dissemination Plan"

Sharing and disseminating key travel information is vital in ensuring all stakeholders, including the public, are informed about service updates or disruptions. TANGENT offered insights in how operational teams could communicate through a centralised platform, though it should be noted that to make the most of this functionality, additional integrations with other data sets, systems and tools would be essential, which could be challenging.

5.1.3.4 "Synchronisation of PT and TC"

Due to a higher-than-expected technical complexity of the module developed in WP5, required by the functionality Synchronisation of Public Transport and Traffic Control, its testing can only be reported by mid-November 2024.

5.1.3.5 "What-if scenarios"

Due to a higher-than-expected technical complexity of the module developed in WP5, required by the functionality What-if simulations, its testing can only be reported by mid-November 2024. However, preliminary results are available in the section 3.5.

5.1.4 TANGENT Dashboard

The TANGENT Dashboard helped emphasise the importance of a single network status view of Greater Manchester's multi-modal transport network.

If the TANGENT Dashboard was made commercially available, it could act as a competitor to some of the existing transport management systems on the market, notably some of the traditional Urban Traffic Management and Control (UTMC) UTMC systems in the UK. Such a tool could also be implemented to complement existing systems, providing better network visibility, response plans and bringing together multiple data streams, allowing for better integration and collaboration across departments and transport modes.

In some cases, the dashboard could replace standalone systems that only monitor specific elements of the network, or that only focus on one particular dataset or asset. By consolidating these into a single platform, operators could improve efficiency, reduce the time spent switching between different tools, and make quicker, more informed decisions.

A key advantage of the dashboard is its ability to simulate response plans for different scenarios, allowing operators to test how the network would react to incidents or disruptions before applying these plans in real time. This simulation capability would provide valuable insight into the effectiveness of interventions and may identify potential issues, enabling engineers to modify response strategies in advance. However, one challenge identified during testing is the length of time required to complete these simulations, which can delay the real-time responsiveness of the system. While these simulations are critical for ensuring that response plans are well-prepared, the time-intensive nature of the process may limit their use during urgent, fast-evolving situations.

However, implementing such a dashboard would come with its own complexities, particularly around data integration. Different datasets come in various formats, and ensuring that they adhere to the same standards is crucial for the dashboard to function seamlessly. Challenges would likely arise in terms of aligning older legacy systems with newer data protocols, ensuring that information is transferred efficiently between public transport, traffic management systems, and other real-time data sources.

Also, the standardisation of datasets across different transport operators (e.g. buses, trams, and highways) could pose additional hurdles, especially in cities like Greater Manchester where services across modes are run by both public and private operators (though there is an ongoing shift towards public ownership). To fully realise its potential, the dashboard would need ongoing updates to accommodate new data sources and technologies (e.g. connected vehicles).

Ultimately, a tool like the TANGENT dashboard could provide enhanced levels of insight for transport authorities, enabling them to not only manage the current state of the network more effectively but also predict and mitigate future challenges. If successfully implemented and marketed, it could set a new standard for multi-modal traffic management systems across Europe.

5.1.5 TANGENT project in general

The TANGENT project has been a significantly valuable experience for TfGM, providing a unique opportunity to collaborate with technical partners in the development of advanced tools and functionalities, particularly the data catalogue and the TANGENT Dashboard. These partnerships allowed TfGM to draw on leading expertise, ensuring that the tools were well-suited to the specific needs of Greater Manchester's diverse transport network.

The data catalogue was key in consolidating a variety of data sources, enhancing TfGM's ability to integrate and utilise this information for transport management. The Dashboard offered a comprehensive, real-time view of the network, with predictive capabilities that help inform more proactive decision-making. Testing these functionalities in a live operational setting within TfGM's control centre was particularly useful, allowing us to observe how these tools could improve day-to-day traffic management, optimise network performance, and support better-informed decisions during peak periods, disruptions and events.

The project aligns with several ongoing work streams at TfGM, including the development of an Intelligent Transport Systems (ITS) platform and the ambition to create a common operational picture across multiple transport modes. By integrating predictive and forecasting features, TANGENT has demonstrated how these tools can enhance operational responses and ensure better coordination across departments and modes. The project has also emphasised the importance of open, accurate, and standardised data, which will be essential as TfGM moves forward in developing technical specifications for future systems and procuring next-generation traffic management tools.

Collaborating with other case study cities throughout the project was also particularly useful. Despite the operational differences between cities, we face similar challenges, such as managing congestion, promoting multimodal integration, and meeting environmental targets. Hearing from the other case studies provided valuable insights into shared goals and strategies. The TANGENT project also provided a European-wide perspective on traffic management, incorporating considerations around environmental, societal, and security issues.

The TANGENT project has broadened TfGM's understanding of the future of transport management, offering valuable insights for shaping operational strategy, technology adoption, and system enhancements. This will enable Greater Manchester to effectively manage its transport network as a dynamic, growing, and increasingly multi-modal city region.

5.2 The next steps once the project is finished

Following completion of TANGENT, TfGM will share lessons learned from the project to ensure benefits and understanding gained are seen across the organisation and with local stakeholders. Sharing insights from testing and real-world implementation will help inform future traffic management strategies and decision-making processes within Greater Manchester.

TfGM will also use knowledge and insights gathered, assessing existing and future traffic management tools and systems. There is potential to enhance functionalities of existing systems through integrating some of the tools and features developed through TANGENT, such as the multi-modal dashboard, customisable views and predictive capabilities. Rethinking how data is collected and shared, especially across modes, will be crucial in achieving a more unified approach to traffic management.

Collaborating with local stakeholders will continue to be a priority, though TfGM is already taking steps to improve this through moving towards a single, public transport operator model through the Bee Network. The project has demonstrated the value in having collaborative workshops to improve multi-actor traffic management, ensuring that all parties involved can work more effectively together to address transport challenges.

TfGM remains committed to participating in R&D projects on a local, national, and European scale, using Greater Manchester as a testbed for innovation. Future projects with a higher Technology Readiness Level (TRL) will be particularly valuable, enabling TfGM to test and implement more mature technologies over longer periods.

This will support TfGM as it continues to evolve its traffic management strategies, ensuring they meet the needs of a growing, multi-modal city region.

6 Conclusions

The deliverable D7.5 aimed to present the activities of the TfGM case study during the development and evaluation of the subsystems and overall systems created by the technical partners as part of the TANGENT project. The initial phase of the activities involved testing the subsystems in collaboration with the technical partners to assess the accuracy of their outputs. Each technical partner provided their own testing methodologies, which varied depending on the subsystem being assessed (e.g., surveys, meetings, document exchanges), and shared their results.

The second phase of the TfGM case study focused on evaluating the overall tool, with subsystems gradually integrated to form the platform’s functionalities. TfGM, with support from relevant partners, assessed the usability, reliability, and accuracy of the dashboard and its functionalities, ensuring alignment with the initial requirements set at the beginning of the project.

The iterative approach to functionality evaluation allowed for ongoing improvements, enabling the tool to be tailored to TfGM’s specific needs. Overall, the testing activities revealed that the dashboard is user-friendly, with clear and relevant data displays. The customisation options are powerful and adaptable, although some elements, such as traffic flow, proved more difficult to present in a user-friendly format. The tool’s complexity and the wide range of features (e.g., planner and customiser functionalities) require time and training to use effectively. A few functionalities remain under assessment due to higher-than-anticipated technical complexities, with testing continuing until the project’s end.

Key insights were gained by TfGM, particularly regarding the need for bespoke, user-specific features for operators. Testing activities helped TfGM identify the differences and intricacies across users, specifically in managing events across the transport network. The demonstration sessions facilitated collaboration amongst stakeholders and team members that will continue after the project concludes.

Another important lesson was the need for reliable and accessible data sources. Despite sharing large amounts of data with technical partners, some elements did not appear on the dashboard due to challenges in processing the data. These activities provided TfGM with a clearer understanding of the technical specifications and functionalities they may require in the future.

The next steps for TfGM include assessing traffic management tools and systems to enhance collaboration and operational capabilities, as well as reviewing how data is collected and shared. These efforts aim to improve multi-modal traffic management across the Greater Manchester region, ensuring better integration of transport modes and more efficient network operations.

7 References

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Annex I: Online survey for the testing of the functionality “Current state of the network”

TANGENT - Testing of the dashboard: STEP 1

From April to September, several tests will be run to assess the different functionalities added progressively on the TANGENT Dashboard. The aim is to carry out these tests on a regular basis, until the complete tool and all its functionalities are tested before the end of September 2024.

This is **STEP 1** of the testing of the TANGENT Dashboard. **This testing runs from April, 3rd to April, 29th**. After this date, the functionality will remain on the dashboard, but its testing will be considered as finished.

STEP 1 consists of testing: TANGENT Dashboard for the current state of the network monitoring, during daily commuting. Please try to answer this form from your experience during peak hours.

To answer this form, you need to access in parallel to the dashboard **XXX**, using the credentials you received by email from "**XXX**".

This form aims to assess 3 aspects of the dashboard:

1. **Usability and reliability**: Evaluate the user-friendliness and the clarity of the dashboard
2. **Accuracy**: Assess the correctness of the data, maps and elements displayed
3. **Compliance with initial requirements**: Review and update of the expectations listed at the beginning of 2023.

Thank you for your participation! Your feedback is extremely valuable for improving the TANGENT dashboard.

The TANGENT testing team.

Introduction questions

What is your full name? *

Votre réponse

What is your role in the city (job title / department / organization) *

Votre réponse

Dashboard Usability and Reliability

This section aims to assess the user-friendliness and the clarity of the dashboard and the functionality.

Use your credentials and access to the TANGENT Dashboard.

Before clicking anything, spend 10-15 seconds looking around the main page.

How do you evaluate the amount of information on the main page? *

	1	2	3	4	5	
Not enough information	○	○	○	○	○	Too much information

The displayed elements (maps, figures) are clear and relevant *

	1	2	3	4	5	
Strongly disagree	○	○	○	○	○	Strongly agree

Let's start playing with the tool!

Click on the top right of a map and select "Expand" to make it bigger. You can move the mouse over the map, zoom in and zoom out, click on elements to get more information. Repeat for other maps as needed.

Is the information on live traffic and incidents (if available) easy to understand? *

	1	2	3	4	5	
Very difficult	○	○	○	○	○	Very easy

Is the information on live public transport easy to understand? *

	1	2	3	4	5	
Very difficult	○	○	○	○	○	Very easy

Any other comment regarding live data?

Votre réponse

Let's customize the dashboard!

If you do not have the access to customize the dashboard, you can skip this question. Otherwise, if you haven't yet, try using the customizer. If you need help, you can take a look at the tutorial video: https://www.youtube.com/watch?v=cybPjJvsNx4

The customization of dashboards is easy to do

	1	2	3	4	5	
Strongly disagree	○	○	○	○	○	Strongly agree

Any other comment regarding customization?

Votre réponse

Global feedback on the TANGENT Dashboard

Overall review of the usability & user-experience of the TANGENT Dashboard

I found the tool unnecessarily complex *

	1	2	3	4	5	
Strongly disagree	○	○	○	○	○	Strongly agree

I found the tool easy to use *

	1	2	3	4	5	
Strongly disagree	○	○	○	○	○	Strongly agree

I would imagine that most people would learn to use this tool very easily *

	1	2	3	4	5	
Strongly disagree	○	○	○	○	○	Strongly agree

Any other comment / question on the user experience?

Votre réponse

Accuracy of the elements displayed

This section aims to assess the correctness of the data, maps and other elements available on the dashboard.

Look at the KPI figures displayed (usually on the top right of the dashboard). Do they seem coherent with the current situation in the area? *

	1	2	3	4	5	
Not at all	○	○	○	○	○	Totally

Does the traffic data displayed on the maps seem coherent with the current situation in the area? *

	1	2	3	4	5	
Not at all	○	○	○	○	○	Totally

Does the incident data displayed on the maps seem coherent with the current situation in the area? *

	1	2	3	4	5	
Not at all	○	○	○	○	○	Totally

Does the public tranport data displayed on the maps seem coherent with the current situation in the area? *

	1	2	3	4	5	
Not at all	○	○	○	○	○	Totally

Does the data displayed when elements are clicked on the maps seem coherent? *

	1	2	3	4	5	
Not at all	○	○	○	○	○	Totally

If you found difficulties in any of the previous elements, please describe them.

Votre réponse

Rennes requirements

Do you think the city data sources are well covered? *

1 2 3 4 5

As a mobility expert, you have listed your expectations for this functionality

Expectation 1: Visualise the current traffic and the congestion in the area defined

Have your initial expectation been met? *

- Totally
- Partially
- No

Expectation 2: See the state of the public transport (buses in the area)

Have your initial expectation been met? *

- Totally
- Partially
- No

Expectation 3: Notice the delay of the various services (buses, shuttles)

Have your initial expectation been met? *

- ◯ Totally
- ◯ Partially
- ◯ No

Expectation 4: Visualise the planned elements that disrupt the traffic (road works, blocked road, etc.)

Have your initial expectation been met? *

- ◯ Totally
- ◯ Partially
- ◯ No

Expectation 5: Display traffic and public transport statistics and choose the granularity

Have your initial expectation been met? *

- ◯ Totally
- ◯ Partially
- ◯ No

Have your initial expectations changed? *

- ◯ Yes
- ◯ No

If the previous answer is yes, what has changed? *

Votre réponse

Any other comment?

Votre réponse