IMPACT ASSESSMENT REPORT

D7.7

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Authors	David Schut, Geert Koops, Pedram Saeidizand (PANTEIA)
Internal reviewers	Lakshya Pandit (Rupprecht Consult), Lucie Tristant (ID4MOBILITY)
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Executive summary

This deliverable summarizes the impacts of three works on the TANGENT project. The deliverable builds upon the case study reports (D7.3, D7,4, D7.5, and D7.6) and links those results to the overall KPIs of the project. The deliverable first maps the four case studies and explains the concept of an impact assessment, followed by a description of the impact assessment methodology, the baseline situation in all case studies, the impacts of the project in the four case studies, and finishes with conclusions and recommendations.

It can be said that TANGENT showed good potential to improve the accessibility in urban areas. This proved to be the case on regular as well as event days (focus of the project). Even when the network seems to be (almost) fully utilized, the TANGENT project found use cases where this optimization could be further improved. The project has the highest impact on KPI1: reducing congestion. From a traffic management perspective, TANGENT provides traffic control centers with extra tools to better spread the traffic flow on the network. But TANGENT proved to be also effective in other domains: positive effect on sustainability (KPI2: CO2 reduction), road safety (KPI3: decrease in accidents), and behavioral change (KPI4: modal shift). Even more important is TANGENT effect on multi-actor cooperation (KPI5). TANGENT strengthen the community of practice working on urban mobility, and improved data integration and exchange among partners.

This impact assessment comes with a set of recommendations on how to build upon the success achieved within the project. The next stage for the tools would be to be tested in real-life. This would make those more interesting to compare the impacts described in this deliverable with the impacts derived from implementation on the ground. Before implementing TANGENT in real-life, the impact assessment recommends to develop complementary demand management strategies to limit the induced demand observed while testing TANGENT use cases. These strategies contain modal shift measures, to use the optimized public transport network among others.

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List of abbreviations and acronyms

Acronym	Meaning
ASAP	As Soon As Possible
B2B	Business-to-Business
B2C	Business-to-Consumer
EC	European Commission
GA	Grant Agreement
KoM	Kick-off Meeting
KPI	Key Performance Indicator
WP	Work Package
C-ITS	Cooperative Intelligent Transport Systems
PT	Public Transport
TfGM	Transport for Greater Manchester
CO2	Carbon Dioxide
KSI	Killed or Seriously Injured
VISSIM	Traffic Simulation Software

1 Introduction

1.1 Background

TANGENT is a project funded by the European Commission under the Research and Innovation Programme, which started in September 2021 and will end in August 2024. TANGENT is coordinated by University of Deusto, based in Bilbao, Spain. The pilot cities involved are Lisbon, Great Manchester, Rennes, and Athens. The main objective of TANGENT is to develop new complementary tools for optimizing traffic operations in a coordinated and dynamic way from a multimodal perspective and considering automated / non-automated vehicles, passengers, and freight transport.

TANGENT allows the precise knowledge and management of the mobility flows among the transport modes and enables the implementation and integration of innovative mobility solutions, services, and business models. The project contributes to more efficient traffic management, by reducing congestion, mitigate environmental effects through CO2 reduction, increasing safety and economic advantage. TANGENT helps the pilot cities to achieve a 10% reduction travel time, 8-10% reduction in CO2 emissions, 5% reduction of accidents,10-15% increase in use of public transport.

1.2 Scope of the impact Assessment

The overall scope of this impact assessment process is to calculate and evaluate specific KPIs, selected among those proposed by the TANGENT cities. The process is made of three main steps that all TANGENT cities have implemented: preparation of the initial plan of the case, assessment of the case study after the implementation and finally a comparison of the KPIs before and after the implementation. However, in some cases, difficulties arose due to the lack of certain results, which impacted the comprehensiveness of the assessment. These gaps required adjustments in the analysis and in some cases limited the ability to draw fully conclusive insights. Despite these challenges, we were able to identify key trends and areas for improvement.

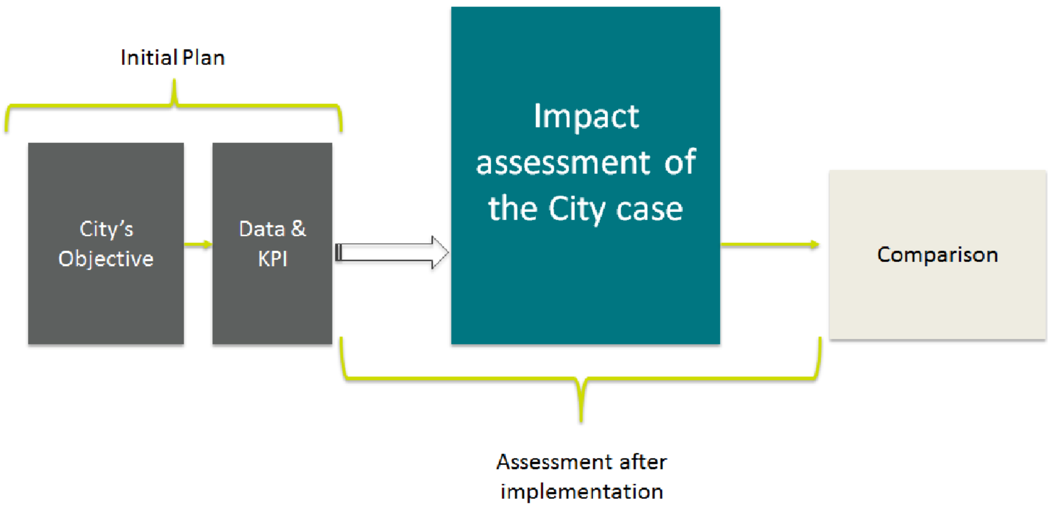

Figure 1: Impact Assessment methodological approach

1.3 Case Studies

1.3.1 Rennes - France

1.3.1.1 Overview

Rennes Métropole is a grouping of 43 municipalities gathering more than 450 000 inhabitants, located in Western France. As a PTA (Public Transport Authority), it runs an efficient public transport network with urban and peri-urban bus lines, car sharing and bike renting as well as 2 metro lines (2nd line to open in 2022). The 2030 mobility strategic plan aims at reducing single occupant cars and increasing public transport as well as cycling and walking. Rennes Métropole is also a “living lab” for mobility innovation and experimentation.

1.3.1.2 Priorities

- Limit the use of private cars by promoting shared modes and giving incentives
- Reduce congestion by working on supply, demand, and regulation
- Limit air pollution
- Reduce accidents for all transport modes
- Integrate all modes in a single offer (private & public operators)

1.3.1.3 Actions

In TANGENT, Rennes Métropole aims at gathering and processing data from different stakeholders (public and private) and providing various schemes for data-sharing to guarantee interoperability and improve intermodality. Tested in a specific area of the city, TANGENT services will provide data visualization, real-time traffic management capacities and information to users so as to regulate traffic incidents, as well as tools to optimize the performance of the network. The priorities are to limit the use of private cars by promoting shared modes, reduce congestion and limit air pollution.

Figure 2: Rennes Case Study Area

1.3.2 Lisbon – Portugal

1.3.2.1 Overview

The metropolitan area of Lisbon has approx. 3 million inhabitants with 5 million person-trips each day. Recent data indicates that over 60,000 cars, 400 buses and 2,000 taxis circulate simultaneously during peak traffic periods. The metropolitan area of Lisbon has a large deployment of big network devices and C-ITS infrastructure in the main highways accessing Lisbon city (A1, A2, A5, A9, and A12). There are also traffic counters and classifiers, variable message, speed and lane control sign information to gather data from the transport network.

1.3.2.2 Priorities

- Traffic optimization
- Incident Management in transport
- GHG emissions reduction

1.3.2.3 Actions

TANGENT aims to integrate data sources from multiple stakeholders, process and disseminate current and future statuses of the network, incidents, speed, route, and park & ride recommendations to users through different channels, including C-ITS infrastructure and variable message panels. The “Smart Network Balance Service” supports a better integration of urban and interurban traffic management in the Metropolitan area of Lisbon by:

- Providing speed and route recommendations for interurban highway flows via C-ITS to connected vehicles.
- Directing vehicles to available off-street and on-street parking spaces and adjusting pricing to balance demand.
- Improving the synchronization of urban public transport with incoming interurban traffic flows from highways.

It is important to note that the Smart Network Balance Service primarily provides a dissemination plan, allowing users to create alerts with parameterized messages based on specific triggering conditions. It does not provide automatic response plans or real-time traffic optimization. In contrast, the “Cooperative Incident Management” service, which was tested in Greater Manchester, focuses on incident response coordination but was not part of the Lisbon implementation.

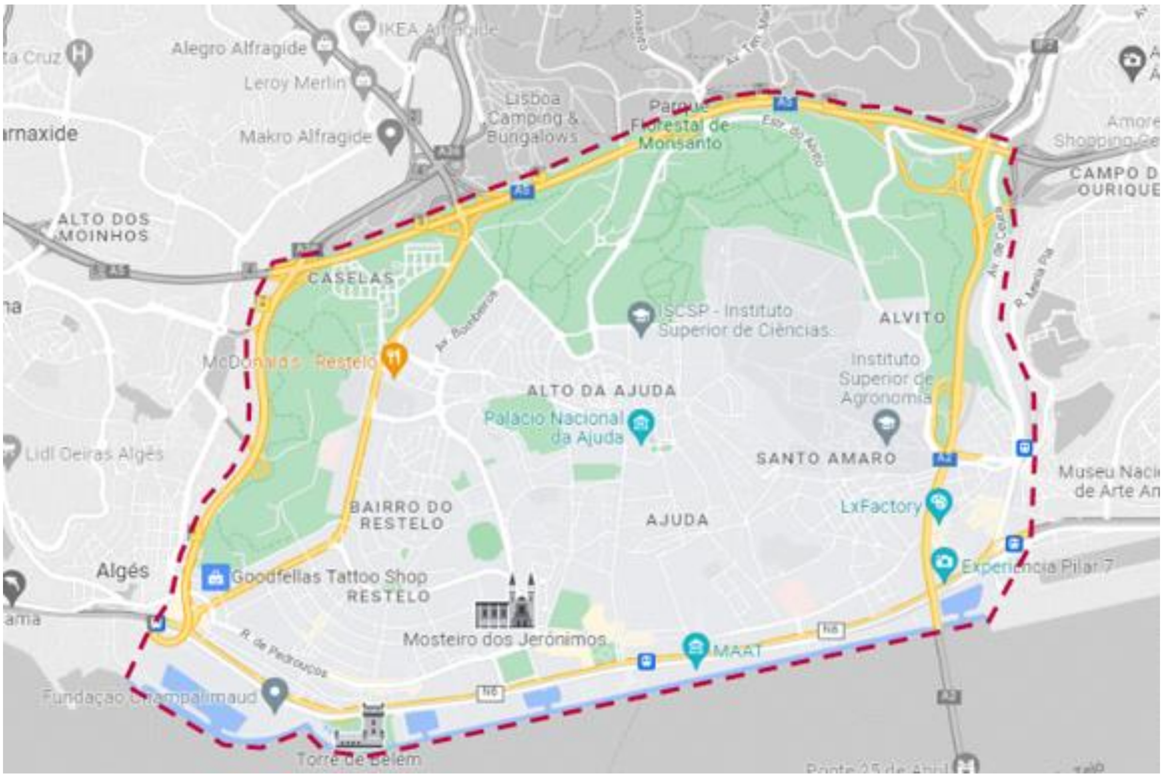

Figure 3: Lisbon Case Study Area

1.3.3 Greater Manchester

1.3.3.1 Overview

Greater Manchester has 2.7 million inhabitants and counts over 5.6 million journeys across its public transport network every day. Greater Manchester will take advantage of existing sensing infrastructure for transport monitoring, such as automatic traffic counters, CCTV, a network of Bluetooth sensor, ANPR (Automatic Number Plate Recognition), C-ITS infrastructure, video analytics sensors.

1.3.3.2 Priorities

- Increase the use of sustainable transport to reduce the negative impacts of car use.
- Reduce greenhouse emissions and pollutants emitted by motorized traffic.

1.3.3.3 Actions

TANGENT maps multi-modal traffic flow and assesses the causes of congestion to identify 'pinch points' in the network. Furthermore, it contributes to improving travel choices, assists in providing customer journey information and encourages sustainable mobility through comprehensive multimodal mobility information, traffic predictions and route recommendations, delivered to users and transport operators.

Through the "Smart Network Load Balance" and "Cooperative Incident Management" services, TANGENT is contributing to optimizing transport in both urban areas and rural/semi-rural regions in Greater Manchester by balancing demand and supply across different modes. The Smart Network Load Balance service provides a dissemination plan, allowing transport authorities and operators to create

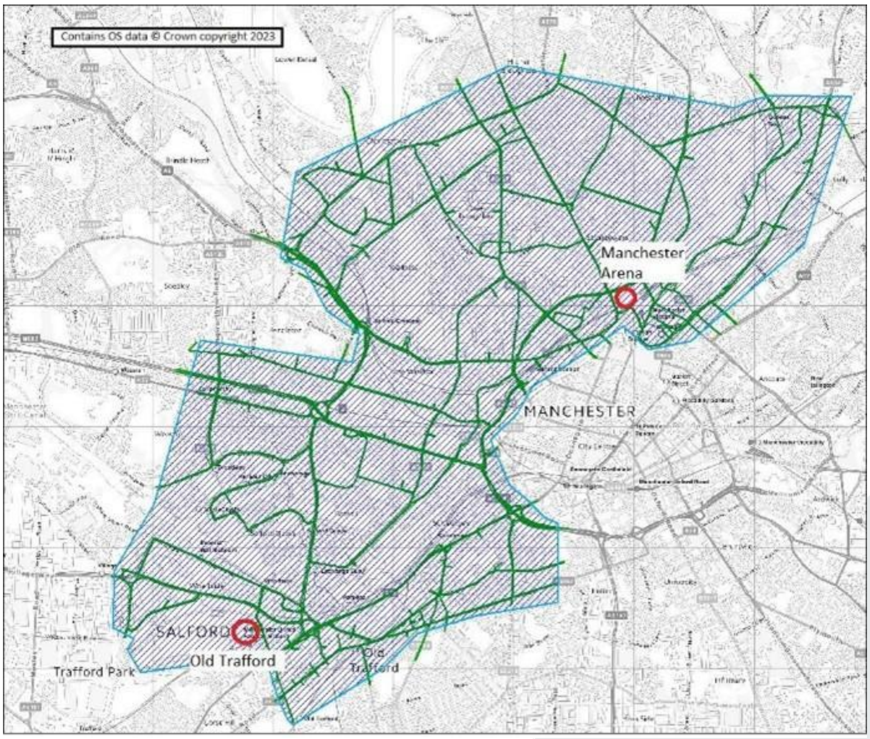

Figure 4: Manchester Case Study Area

alerts with parameterized messages based on specific triggering conditions. It suggests various strategies to improve traffic flow, including alternative traffic signal timings, variable speed limits, re-routing, pricing, and incentives, with a focus on promoting sustainable transport modes. In contrast, the "Cooperative Incident Management" service focuses on coordinating responses to incidents, providing real-time support to improve traffic management during disruptions.

1.3.4 Athens

1.3.4.1 Overview

Athens is one of the largest economic hubs in Southern Europe. Yet, it faces severe congestion challenges due to the rising demand for car trips and a lack of coordination between modes.

1.3.4.2 Priorities

- Improve network connectivity and reduce congestion, by pursuing the urban regeneration project "Grand Walk", which aims to free up 50.000 square meters of urban space to pedestrians and soft mobility.

1.3.4.3 Actions

TANGENT aims to provide strategies to improve network connectivity and operations through a better information system that connects all modes of transportation. In addition, TANGENT focuses on significantly reducing congestion through the balance of demand and supply in real-time scenarios. The efficiency of TANGENT's strategies is tested on various future mobility scenarios including CAVs (Connected and Automated Vehicles) and ride sharing services.

Figure 5: The Athens metropolitan area and the inner-ring (case study area) in red

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

The structure of the deliverable is straightforward. The next chapter describes the methodology of the impact assessment per case study. The third chapter describes the baseline situation before the implementation of the TANGENT tools/use cases. In the fourth chapter, the (potential) impact of the TANGENT project is assessed. The deliverable closes with the conclusions and recommendations.

This deliverable touches on most of the other work packages. It builds upon the results of:

- WP1 – outcomes of the stakeholder workshops to assess KPI on multi-actor collaboration.
- WP2 – observed data collected within the data catalogue.
- WP3 – outcomes of the stated preferences research to estimate potential modal shift.
- WP5 – assess potential effects using the results of the simulation of use cases and what-if scenarios.
- WP7 – use the results from the case studies and analyzing those to assess the impact of TANGENT.

2 Methodology

To monitor the impact of the project, the consortium established 6 general KPIs with specific targets for each case study, which you can find in the table below. This chapter describes how the TANGENT partners monitored the KPIs they want to focus on. Effective monitoring will enable a swift evaluation at the end of the project, when an impact assessment of the project has been conducted.

As pointed out earlier, the first step of the process is preparation of the initial plan and builds on two main pillars: City's objective (1) and Data & KPI (2). City's objective: where the Cities have depicted the primary and secondary objectives of the case implementation as important elements to be assessed during the test. Data & KPI: it refers to the activity of reporting on source data ('Data)' that have been collected by the Cities, and to the activity of reporting the KPIs that have been calculated after the implementation phase.

Second step ('Assessment after implementation' in the schema above) reports for each criterion (e.g. Mobility, Environment and Safety) the quantitative/qualitative value of the KPI calculated before the pilot/case study implementation and after. This section describes, for each indicator, if calculation was possible, the method used for the calculation and any remarks or comments.

Finally, step three ('Comparison' in the schema above) prepares for each City case a qualitative/quantitative assessment of the results of the calculation of the KPIs. It reports on the delta of the KPIs' values calculated before and after the implementation, assesses if the planned objectives and impacts have been respected and achieved or if any modification has occurred.

Certain KPIs have a goal year that is beyond the project deadline. For this reason, the targets concerned have been simulated using the TANGENT solution, and the other KPIs results, mixed with extrapolations and projections. In the following paragraphs, the strategy of each case study is presented, according to their targets. The data sources consulted for KPIs could be different in terms of nature or the method to compile data in cities. It should be noted that this may have influenced the outcome of the assessment.

Targets per KPI for each case study	KPI 1: Reducing congestion	KPI 2: Reducing pollution	KPI 3: Reduction of accidents	KPI 4: Changes in behavior	KPI 5: Cooperation with all actors	KPI 6: Information for decision-making
Greater Manchester	- Reduce travel times by 10% at peak hours. - Decrease speed variability by 10%. - Improve junction performance by 10% at	- Reduce CO_2 emissions by 13% each year. - TFGM commitment to zero carbon by 2038.	- Reduce 2-5% KSI's year on year (KSI: killed or seriously injured).	- Increase walking and cycling by 10%. - Increase public transport use by 10%. - Right mix agenda – 50% of all journeys to be made by sustainable modes by 2040.	None	None

Targets per KPI for each case study	KPI 1: Reducing congestion	KPI 2: Reducing pollution	KPI 3: Reduction of accidents	KPI 4: Changes in behavior	KPI 5: Cooperation with all actors	KPI 6: Information for decision-making
	10 key junctions as identified by TANGENT.					
Lisbon	- 10% reduction in person-hours lost due to congestion by 2030.	- Reducing by 10% the Greenhouse Gas emissions by 2030. - Reduction of air pollutant emissions (at least 10%) and noise.	- Reducing serious injuries in 5% in 2030.	- 7% of public transport increase.	- 10% increase on automatically managed incidents with multiple stakeholders.	- Provision of information to inform the public and decision-makers at least on 2 major transport investments. - Development of a tool to support planning for specific events (planned and unplanned) and simulations for at least 5 planned events.
Rennes	- Reducing number of cars by 10% at peak hours.	- Reducing by 2030 by 15% CO2 emissions.	- Decreasing the number of accidents by 10% for 2030.	- Reduce 10% share for motorized vehicles. - From 3% to 9 % for bicycles share. - From 28% to 35 % for walking.	- Creation of a community of mobility operators (public/private) for adopting joint strategies for respecting the other KPIs.	None

Targets per KPI for each case study	KPI 1: Reducing congestion	KPI 2: Reducing pollution	KPI 3: Reduction of accidents	KPI 4: Changes in behavior	KPI 5: Cooperation with all actors	KPI 6: Information for decision-making
				- From 10% to 15 % for using public transport and increasing the commercial speed to 17 km/h in urban environment and to 30 km/h outside the city.	- Cooperation agreements to be signed on data provision and impact of modes' monitoring processes.	
Athens	- Reduce travel times by 10% at peak hours. - Decrease speed variability by 10%.	- Reduce vehicle CO_2 emissions by 5% in total and by 12% during peak hours.	- Reduce the number of accidents by 2%. - Reduce the number of conflicts by 5%.	- Increase transit use by 9% on average. - Decrease car use by 15% in the city center.	- Community of at least 10 mobility operators (public/private) involved in the assessment of the virtual Case Study. - Cooperation agreements to be signed on data provision and impact of modes' monitoring processes.	None

Table 1: KPIs and targets per case study

2.1 Rennes

KPI 1: Reducing congestion

Rennes Target: Reducing number of cars by 10% at peak hours.

To monitor this target, we have used existing sensors on the perimeter area "Route de Lorient" that measure the flow rate and the occupancy rate every 3 minutes (see the figure below, the green lines represent the road sections where this information is detected).

Figure 6: Sensors location on the case study area

Mainly, the data set REN_TRAF_07 from Rennes Métropole Control Center PC Arthur has been used to quantify this target.

At the end of the experimentation, the historical data has been analyzed to create a chart and visualize the evolution of the traffic congestion from M0 to M36, with three main phases:

- Phase 1: M0 to M19: before the experimentation
- Phase 2: M20 to M31: during the experimentation, with gradually more and more services implemented during these months
- Phase 3: M32 to M34: during the experimentation, with all the services tested at the same time

The observed data from the three timeframes will be supported by simulation output from WP5. This simulation helps to isolate the (potential) effect van TANGENT from the observed data.

KPI 2: Reducing pollution

Rennes Target: Reducing by 15% CO_2 emissions by 2030.

The target initially defined for Rennes' case study about this KPI is high-level as it aims to be measured in the long term. To identify the evolution of pollution during the scope of the project, a short-term evaluation method has been implemented focusing on air quality and CO_2 emissions.

Projections using KPI1 results has been done: the CO_2 emissions generated by the number of cars not circulating anymore at the end of the project can be determined with hypothesis and extrapolations. This data is supported by simulation output from WP5. Within Aimsun Next software, also the reduction in CO_2 emissions after an intervention can be extracted.

KPI 3: Reduction of accidents

Rennes Target: Decreasing number of accidents by 10% for 2030.

The measurement of this target has been done through simulation, focusing on the RN 24 (National Road, Route de Lorient), and taking into consideration the results from the baseline scenario data regarding traffic and public transport. This is done by using the traffic flow improvement as a proxy and multiply this with the correlation between traffic flow and road safety[1].

KPI 4: Changes in behavior

Rennes Targets:

- Reduce 10% share for motorized vehicles.
- From 3% to 9 % for bicycles share.
- From 28% to 35 % for walking.
- From 10% to 15 % for using public transport and increasing the commercial speed to 17 km/h in urban environment and to 30 km/h outside the city.

This KPI is challenging as it is composed of several targets to reach, that has been mainly measured with simulation. The evolution of the motorized vehicles share has been assessed with the historical traffic. This data is supported by simulation activities within WP5 and behavioral studies done in WP3.

KPI 5: Cooperation with all actors

The target associated with KPI5 (Cooperation with all actors) is quantitative and has been measured by listing the actions done, especially the number of initiatives made gathering public and private operators (regular meetings, joint actions to measure and reach the other KPIs, etc.). This information was gathered during stage 3 WP 1 workshop in Rennes.

2.2 Lisbon

KPI 1: Reducing congestion

Lisbon Target: 10% reduction in person-hours lost due to congestion by 2030.

To assess the fulfilment of this target, the average congestion has been tracked in the main roads of the case study area (refer to chapter 3.2.1) during the MPH and APH periods. To capture evolutions, the measurements has been performed throughout the testing phases (prior, during and after the implementation of the TANGENT services). The congestion has been measured using the following indicators:

- The average travel speeds and traffic delays are a straightforward measure of the overall congestion in the area;
- The registered delays in the CARRIS lines can capture the impact of congestion for people using PT modes;
- The number of vehicles counted by road/traffic sensors helps get a better notion of the number of vehicles circulating in the area, and filter delays due to other causes.

As the proposed KPI is a long-term goal, the impacts of the TANGENT services in improving this target cannot feasibly be measured within the scope of the testing stages. Thus, the potential long-term effects have been extrapolated through simulation, using the measured indicators as a baseline.

[1] https://www.sciencedirect.com/science/article/pii/S0967070X21000731

KPI 2: Reducing pollution

Lisbon Targets:

- Reducing by 10% the Greenhouse Gas emissions by 2030.
- Reduction of air pollutant emissions (at least 10%) and noise.

The evaluation of this target has been performed through simulation, using estimated emission indicators extrapolated from the traffic congestion indicators (see KPI 1) as a proxy.

There are air quality and noise sensors scattered around the city of Lisbon, with 7 being located within or near the perimeter of the case study area. The collected indicators are open data; however, they sometimes became unavailable due to various technical reasons, rendering them an unreliable source for the purpose of testing the TANGENT services. Thus, when available during the testing phases, the sensor measurements have been used to validate and complement the simulation model estimations.

KPI 3: Reduction of accidents

Lisbon Target: Reducing serious injuries by 5% in 2030.

The assessment of this target has been done through simulation, using critical conflicts to assess the impact on traffic safety. The simulation will focus on the A5 motorway, which is already replicated in the VISSIM microscopic model. The historical data regarding conflicts can be used as a baseline to project potential evolutions due to the deployment of the TANGENT services.

KPI 4: Changes in behavior

Lisbon Target: 7% of public transport increase.

To assess the fulfilment of this target, the demand on the selected CARRIS lines has been tracked (refer to chapter 3.2.1). To capture evolutions, the measurements has been performed throughout the testing phases (prior, during and after the implementation of the TANGENT services). The PT demand has been measured using the following indicators:

- The number of ticket validations during the MPH and APH periods is a straightforward measure to assess the changes in the PT demand in the region.
- The number of ticket validations for broader intervals (such as weeks or months) can also be used to detect demand evolutions that occur outside the testing periods.
- The number of vehicles counted by road/traffic sensors helps assessing if observed PT demand changes are effectively due to a modal shift, or if they may be caused by external phenomena.

As the proposed KPI is a long-term goal, the impacts of the TANGENT services in improving this target cannot feasibly be measured within the scope of the testing stages. Thus, the potential long-term effects have been extrapolated through simulation, using the measured indicators as a baseline.

KPI 5: Cooperation with all actors

Lisbon Target: 10% increase in automatically managed incidents with multiple stakeholders.

The evaluation of the fulfilment of this target has been performed by listing the endeavors made to display the TANGENT services to external stakeholders, as well as the enumeration of those successfully engaged in the testing stages of both the subsystems and the final tool. This exercise was done in the aftermath of the WP1 stage 3 workshop in Lisbon.

KPI 6: Information for decision-making

Lisbon Targets:

- Inform the public and decision-makers at least on 2 major transport investments.
- Development of a tool to support planning for specific events (planned and unplanned) and simulations for at least 5 planned events.

The assessment of this KPI has been conducted by listing the instances where the simulation model is employed to evaluate changes in the PT service provision, namely the deployment of the what-if scenario simulations to prepare planned events, or to design in local pilot tests.

2.3 Manchester

KPI 1: Reducing congestion

TfGM Target:

- Reduce travel times by 10% at peak hours.
- Decrease speed variability by 10%.
- Improve junction performance by 10% at 10 key junctions.

The above high level KPI's have been addressed by more specific KPI's and simulation methods utilized to predict longer term impacts.

Traffic management systems, providing decision making support tools and channels to provide customer information, are known to improve journey times and reduce the impact of congestion. TfGM have reported on the impacts of various traffic management interventions utilizing a number of data sources, as part of many monitoring and evaluation exercises. It was intended to utilize the same format of assessment to measure the benefits of the TANGENT Services.

A key benefit of implementing the proposed TANGENT Services compared to the minimum scenario has been that the improved communication and information regarding traffic conditions on the identified network, enabling management of traffic flow by providing early warning to operators to allow traffic management interventions to be implemented, to prevent congestion. This was expected to provide journey time saving benefits for both road and public transport users.

Evaluation method:

The main source of data has been TFGM_CARS_04 - Real time journey time data from Bluetooth sensors. This has been complemented by TFGM_CARS_16 - Crowd sourced journey time data obtained by Waze, tracking its app users.

Routes monitored have been those that facilitate ingress/egress to the regional centre, within the identified case study area:

- *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*

Similar to the above, bus journey time has been monitored, the data sources that have been utilized are: TFGM_BUST_03 real time bus location via AVL (Automatic Vehicle Location system).

Bus services that operate in the identified case study area that have been monitored, as outlined - Bus Services: X50, 255, 250, 256 V1, V2, 67, 100, 97, 98, 33, 34.

KPI 2: Reducing pollution and KPI 3: Reduction in the number of accidents

TfGM Target:

- Starting - 13% year. TFGM commitment to zero carbon by 2038.
- Reduce 2-5% KSI's year on year (KSI: killed or seriously injured).

KPI 2 and KPI 3 has been assessed through simulation, taking into consideration the results from the journey time monitoring for both general traffic and bus. Simulation under WP5 provided also data on (potential) effects on CO_2 emissions.

KPI 4: Changes in behavior

TfGM Target:

- Increase walking and cycling by 10%.
- Increase public transport use by 10%.
    - Supporting the Right mix agenda – 50% of all journeys to be made by sustainable modes by 2040.

Without access to PT patronage data, assessment of this KPI is challenging. Monitoring of traffic count sites can be used to help establish understanding of modal shift and movement towards the 'right mix agenda'. As the proposed KPI is a long-term goal, the impacts of the TANGENT services in improving this target cannot feasibly be measured within the scope of the testing stages. Thus, the potential long-term effects has been extrapolated through simulation, using the measured indicators as a baseline.

2.4 Athens

For evaluating the impact of the TANGENT services in the Athens inner-ring urban transportation network, the outcomes of all services' related (simulated) scenarios have been compared to the baseline scenarios. The main outcome of this evaluation method is the quantification of selected Key Performance Indicators (KPIs) for all scenarios. The selected KPIs for the Athens case study are the following:

- KPI1: Congestion reduction: Congestion reduction has been quantified, in the framework of the Athens case study, by taking into consideration the travel times of the vehicles, as well as their speed variability in all scenarios.
- KPI2: Pollution reduction: Pollution reduction has been quantified, in the framework of the Athens case study, by quantifying the CO_2 emissions in the scenarios.

- KPI3: Traffic safety: Traffic safety is to be examined by quantifying, for all scenarios, the number of critical conflicts between vehicles.
- KPI4: Modal shift: Modal shift, towards Public Transportation, has been quantified, in the framework of the Athens case study, through transit use change, and car usage decrease.
- KPI5: Cooperation of all actors: The cooperation of all actors has been guaranteed by involving at least ten (10) mobility operators (public/private) in the assessment of the results of the Athens case study.

The selected KPIs fully capture the impact that TANGENT services will potentially have on the traffic conditions of the Athens inner-ring urban transportation network.

3 Assessment: Baseline

3.1 Rennes

KPI 1: Reducing congestion

Rennes first target under KPI 1 is to reduce the number of cars with 10% in peak hours. A number of 125,000 to 200,000 cars use the rue de Lorient on a daily basis. However, the number of cars in itself does not indicate congestion. Therefore, the baseline study assessed average speed and travel time. The average vehicle speed ranged from 41.97 km/h to 48.44 km/h between May 10, 2023, and May 18, 2023 (see figure 7), while the average travel time varied from 8 to 11 minutes (see figure 8). The highest vehicle speeds were recorded on May 18, 2023 (48.44 km/h), while the lowest speeds were observed on May 10, 2023 (41.97 km/h). Over most days, the travel time remained stable between 9 to 11 minutes, indicating a relatively consistent level of congestion throughout the study period. Despite a football match on the 14th, the congestion was actually less than the previous days.

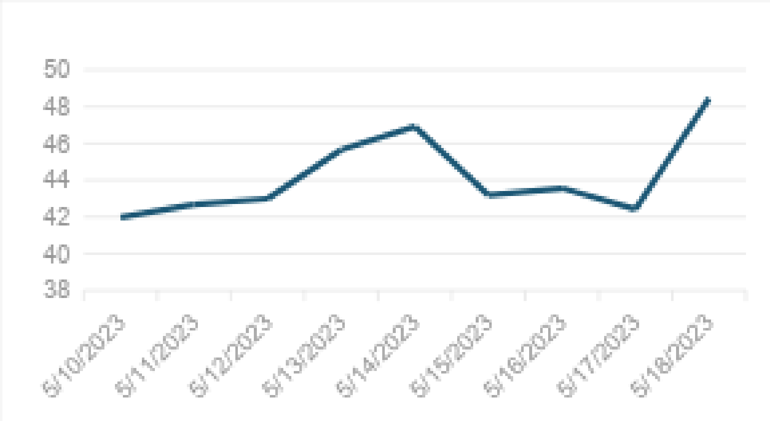

Figure 7: Average vehicle speed in km/h

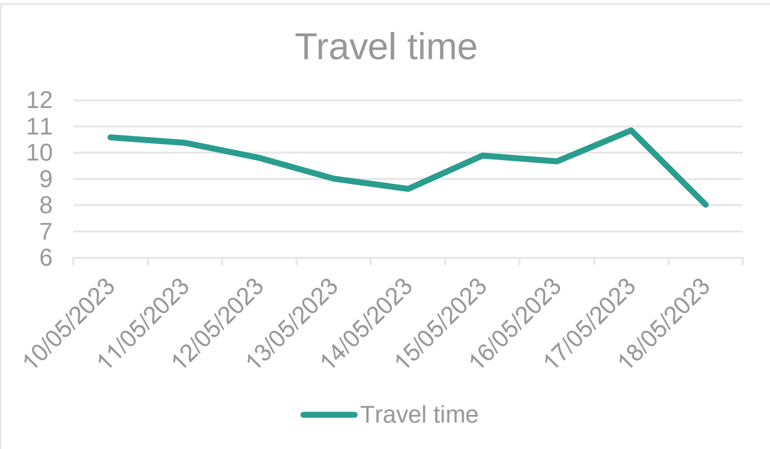

Figure 8: Travel time in minutes

KPI 2: Reducing pollution

Rennes target under KPI 2 is to reduce the CO_2 emissions on the rue de Lorient with 15% by 2030. The CO_2 emissions data for Rennes between May 10 and May 17, 2023, shows a fluctuation around the average value of 653 kg co2 (see figure 9). The emissions peaked on May 15, 2023, at 717 kg per day, while the lowest emission was recorded on May 13, 2023, at 461 units. The variation in emissions correlate with the number of vehicles on the road, as the days with higher emissions generally align with higher vehicle flow, such as on May 11, 14, and 15. These days also had the highest number of cars circulating, with totals reaching up to 194,410 vehicles.

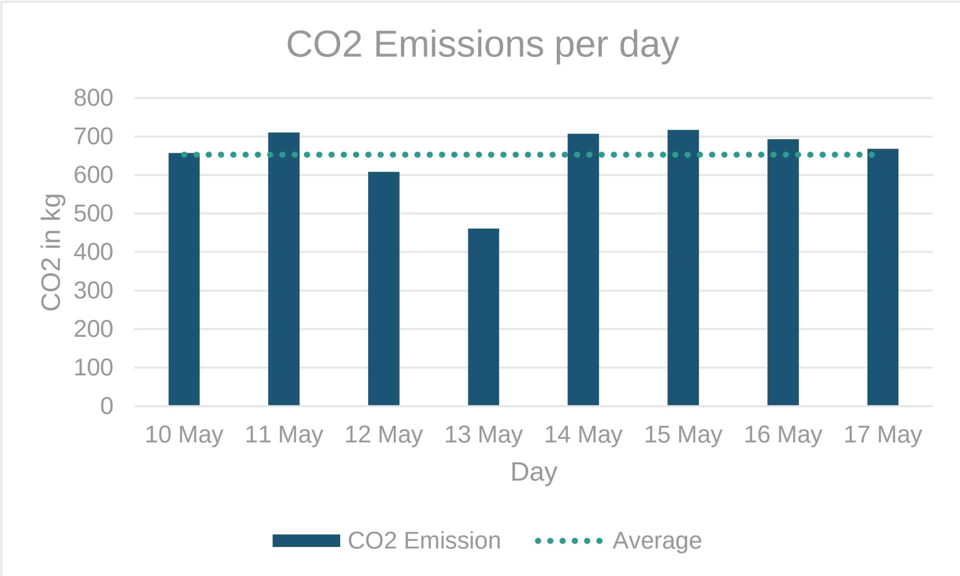

Figure 9: CO_2 emissions per day in **kg**

KPI 3: Reduction of accidents

No reliable numbers on the number of accidents are available for the case study area. The KPI is to reduce the number of accidents by 10% in 2030. Data from the start of the project showed that 464 accidents have taken place in Rennes in 2023 that caused serious injuries[2].

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2 https://data.rennesmetropole.fr/explore/dataset/accidents_corporels/analyze/?dataChart=eyJxdWVyaWVzIjpbeyJjb25maWciOnsiZGF0YXNldCI6ImFjY2lkZW50c19jb3Jwb3JlbHMiLCJvcHRpb25zIjp7fX0sImNoYXJ0cyI6W3siYWxpZ25Nb250aCI6dHJ1ZSwidHlwZSI6ImxpbmUiLCJmdW5jIjoiQ09VTlQiLCJ5QXhpcyI6Im9iamVjdGlkIiwic2NpZW50aWZpY0Rpc3BsYXkiOnRydWUsImNvbG9yIjoiIzY2YzJhNSJ9XSwieEF4aXMiOiJ3bXNfdGltZSIsIm1heHBvaW50cyI6IiIsInRpbWVzY2FsZSI6InllYXIiLCJzb3J0IjoiIn1dLCJkaXNwbGF5TGVnZW5kIjp0cnVlLCJhbGlnbk1vbnRoIjp0cnVlfQ%3D%3D

Year	Number of accidents
2021	550
2022	509
2023	464

Table 2: Number of road accidents in Rennes

KPI 4: Changes in behavior

In 2018 the share of motorized traffic in Rennes was 48,5%. The KPI within TANGENT is to decrease this percentage with 10%. To increase the current 3% modal share of cycling to 9% (and with that align with the objectives in the urban mobility plan for Rennes). Also, to increase walking from 28% (current level) to 35%. For Public Transport the KPI is to increase the current modal share of 13,7% to 15%[3].

KPI 5: Cooperation with all actors

The aim of Rennes with the TANGENT project is to create a community of mobility operators via the engagement in the TANGENT project. This community will be formalized by signing a cooperation agreement among the different stakeholders participating in the TANGENT project. At the beginning of the project the Case Study managed well to include new stakeholders and communicate with them. Also the open data system from Rennes Metropole was appreciate within the wider community. Aspects that could be improved via the project were informing the public, integration of tools, and improve the data flow between different stakeholders.

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

3.2 Lisbon

KPI 1: Reducing congestion

Lisbon's first target under KPI 1 is to reduce 10% person-hours lost due to congestion by 2030. On average, the travel delay for cars in the Lisbon Case Study area ranged between 69.1 and 97.1 seconds (see figure 10). The time frame was from February 19, 2024 to February 23, 2024. With a peak of 97.1 seconds on Thursday, February 22. In contrast, the least congestion is seen on Monday, February 19, with an average congestion of 69.1 seconds per reported traffic jam in Waze.

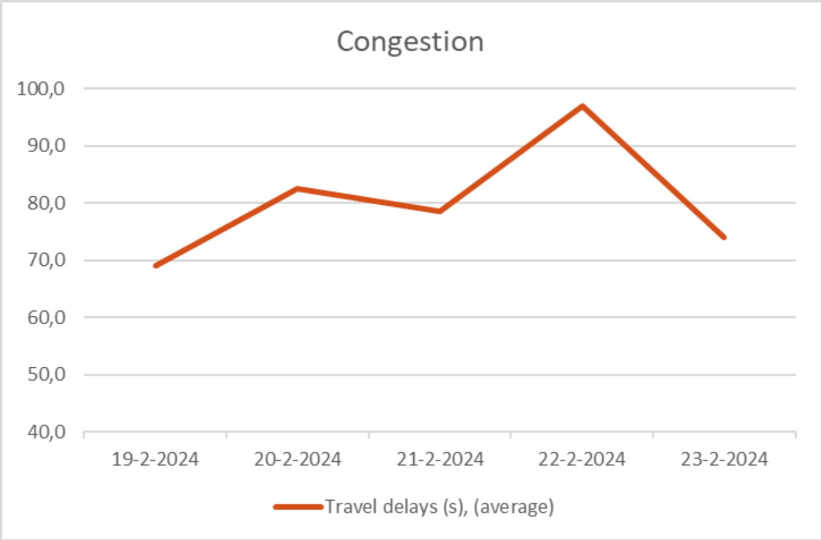

Figure 10: Average travel delays (s) for cars in Lisbon

The total number of delays on Carris bus and tram routes in Lisbon ranged between 134 and 161 delays per day between February 19, 2024 and February 23, 2024 (see figure 11). On Thursday, February 22, the fewest traffic delays were observed, namely 134.

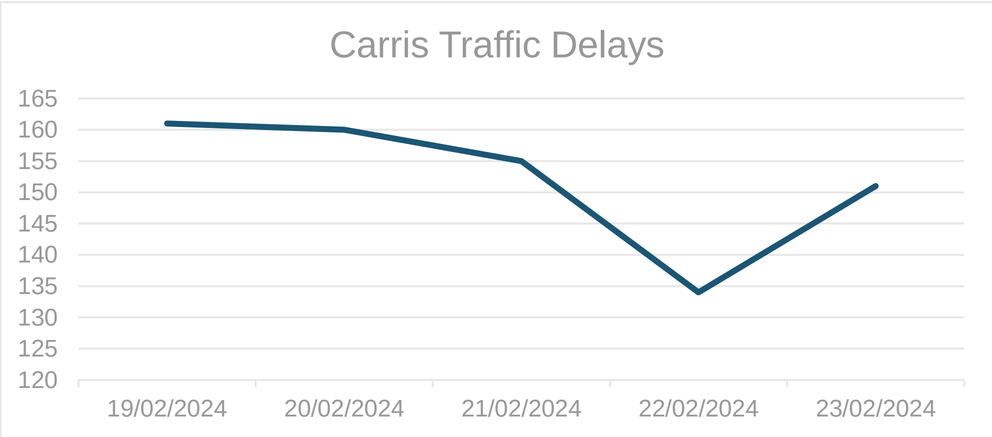

Figure 11: Carris traffic delays

KPI 2: Reducing pollution

Lisbon's target under KPI 2 is to reduce the CO2 emissions by 10% by 2030. The CO2 emissions data for Lisbon Case Study area, has an average value of 1.947 kg CO2 (see figure 12). On February 20, the highest emission of CO2 was measured, 1.975 kg. In contrast, the lowest concentration of 1.887 kg was measured on February 19.

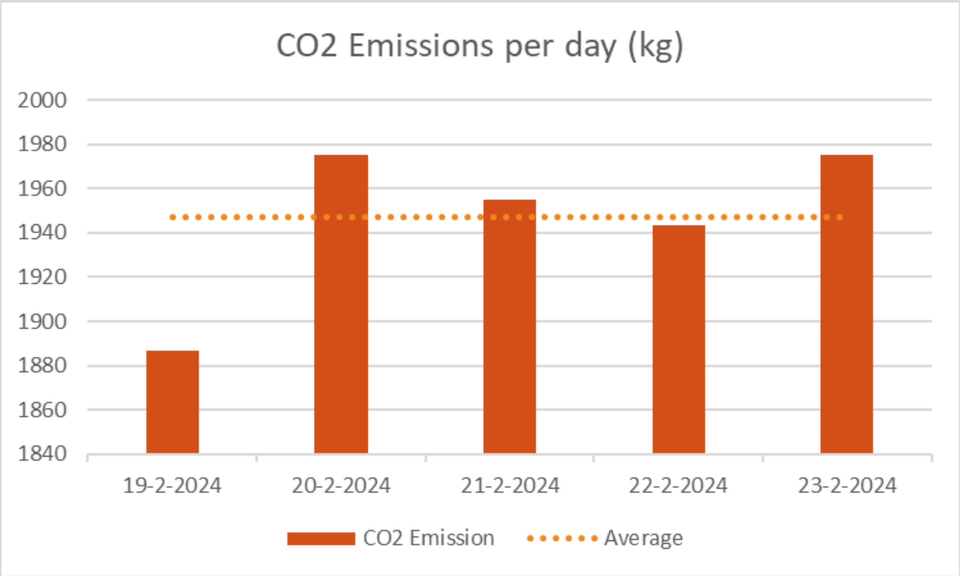

Figure 12: CO2 Emissions per day (kg) in Lisbon

KPI 3: Reduction of accidents

No Case Study specific accident data could be obtained. Therefore, data for Lisbon as a whole was used to analyze the baseline situation. In 2022 6.835 accidents occurred that resulted in serious harm to at least one of the sides involved. In 2023 this number increased to 7.245[4]. Within TANGENT, the city of Lisbon aims to reduce the number of accidents in the Case Study area with 5% in 2030.

KPI 4: Changes in behavior

The target under KPI 4 for Lisbon is to increase the use of public transport by 7%. The chart below (figure 13) shows the number of check-ins per Carris bus line per day. Most check-ins occur each day on bus line 728. On this bus line, the number of check-ins during the days of measurement ranged from 4574 to 5652. In contrast, the fewest check-ins were measured on bus line 79B during the measurement days, fluctuating between 38 and 162 check-ins. You can see the distribution of the other bus lines in the graph below. The total number of check-ins, in the Case Study area, fluctuates between 20.577 and 23.656 check-ins.

[4] http://www.ansr.pt/Estatisticas/RelatoriosDeSinistralidade/Pages/default.aspx

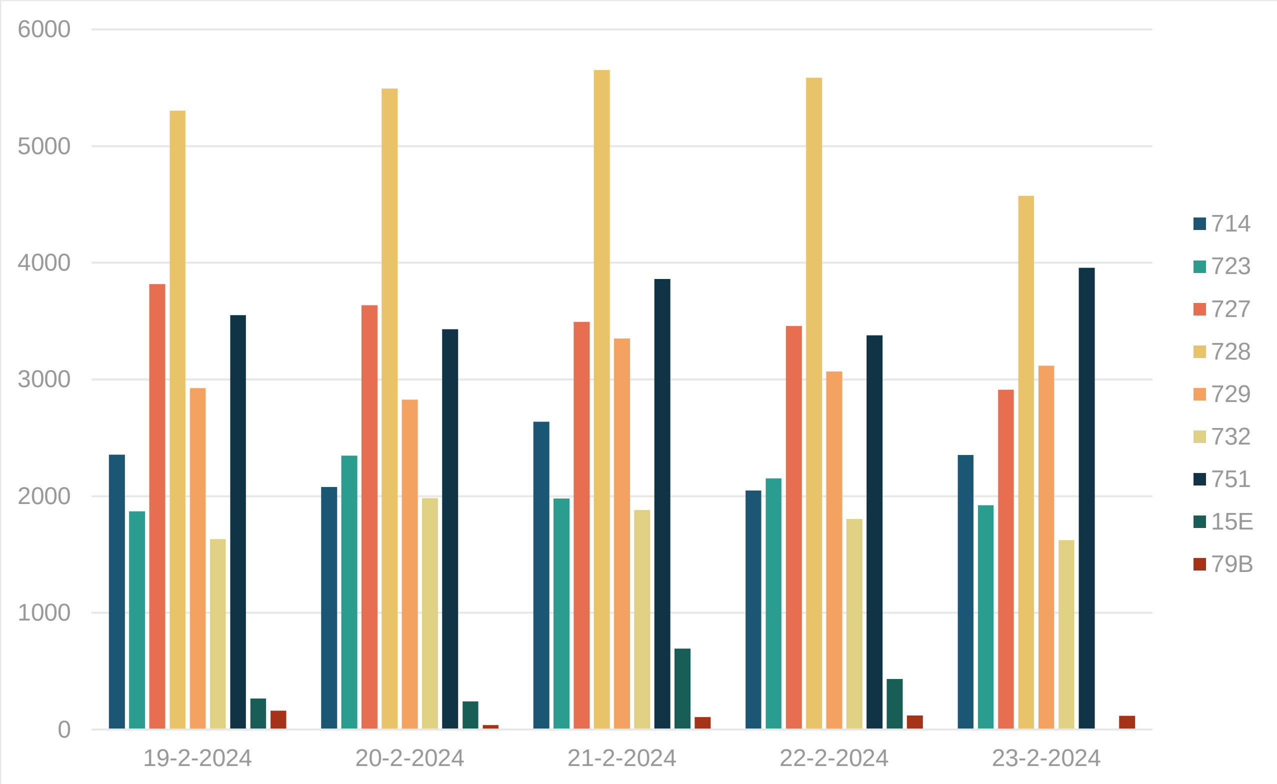

Figure 13: Number of check-ins per Carris bus line

Date	Total Check-Ins
19-2-2024	21879
20-2-2024	22075
21-2-2024	23656
22-2-2024	22049
23-2-2024	20577
Total Check-Ins	**110236**

Table 3: Total check-ins (accumulation of all bus lines)

KPI 5: Cooperation with all actors

Stakeholders with Lisbon's traffic management ecosystem knew from the beginning of the project to find each other well. Only the limited data exchange and the decentralized data collection posed a challenge to the TANGENT project. Incident management was often done manually with and not based on live information. Therefore, the target was to increase automatically managed incidents including multiple stakeholders with 10%.

KPI 6: Information for decision-making

The aim of the city of Lisbon is to inform the public on 2 major transport investments during the implementation of TANGENT. It can only be foreseen whether this aim was implemented successfully at the very end of the project.

3.3 Manchester

KPI 1: Reducing congestion

Manchester's first target under KPI 1 is on reducing travel times by 10% at peak hours. The data on average journey times for cars in Manchester from late May to early June shows a noticeable variation, with journey times ranging from a high of 121 seconds on May 25th to a low of 89 seconds on May 29th (see figure 14). The second target under KPI 1 is to reduce speed variability by 10%. The overall average journey time across this period is approximately 105 seconds. This variation in travel times indicates the traffic congestion, with certain days, like May 25th and 26th, experiencing higher congestion levels, leading to longer travel times. In contrast, days like May 29th and 30th saw lower congestion and thus shorter journey times. This can partially be explained by the Elton John concerts in the 02 Arena in Manchester on 31-5, 2-6 and 3-6. The time to cross the case study area increases by 30% during those events. This shows the potential for the TANGENT tools to reduce this increased travel times by managing the traffic crowds more efficiently. The third target under KPI 1 is to improve the junction performance by 10%. However, there is no specific data on junction performance (i.e. waiting times) available, but average travel times can be considered as a proxy.

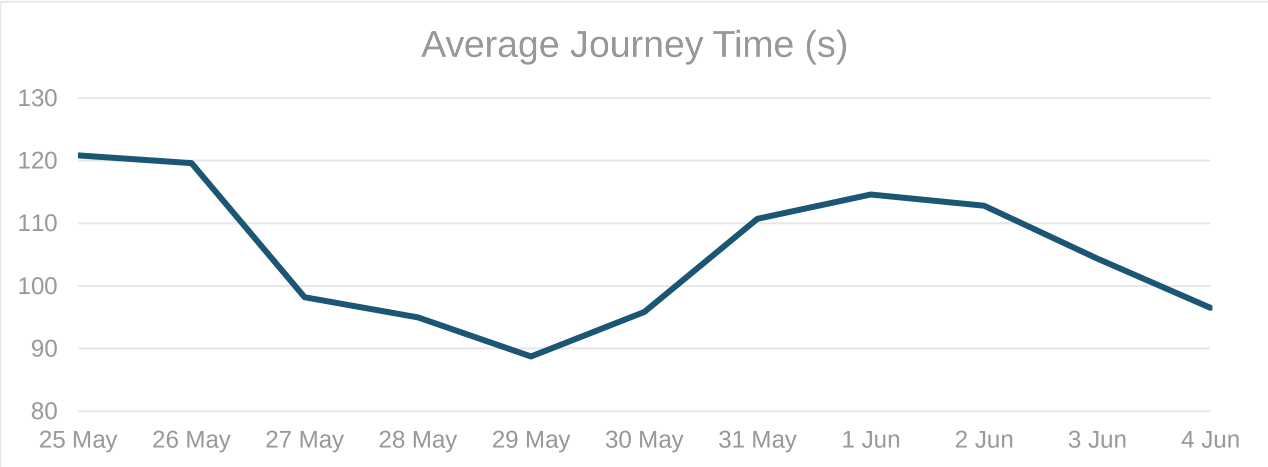

Figure 14: Average journey time for cars in seconds

The figure below reveals that travel times for different busses vary significantly between different bus lines and days. Notably, the average travel times for V2 and X50 are significantly lower compared to the other lines, with X50 exhibiting the shortest travel time of all.

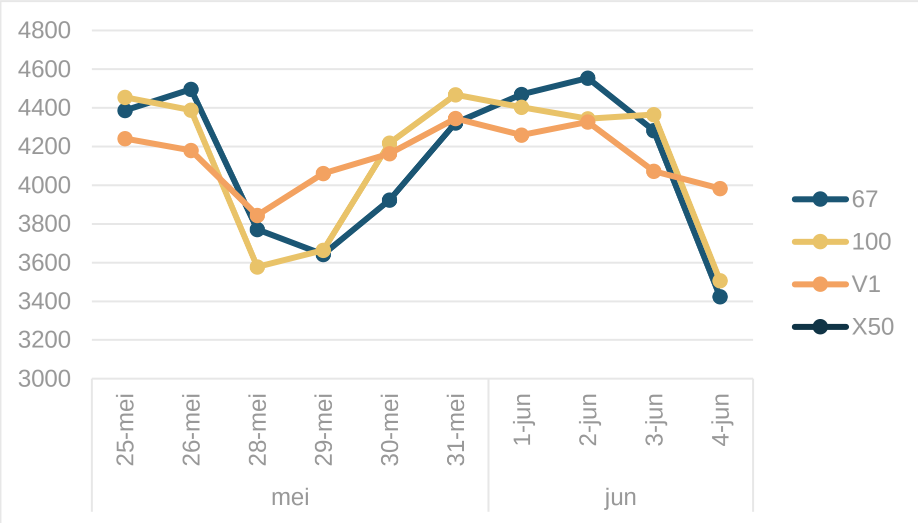

Figure 15: Average journey time for different bus lines in seconds

KPI 2: Reducing pollution and KPI 3: Reduction in the number of accidents

Transport for Greater Manchester aims to reduce transport-related emissions by 13% per year. The figure below presents the current daily CO_2 emissions recorded over a period from May 25 to June 4. The daily CO_2 emissions range from 178kg to 252kg. On average, the CO_2 emitted on a day with an event in the case study area was 221kg during the week of May 25 to June 4th.

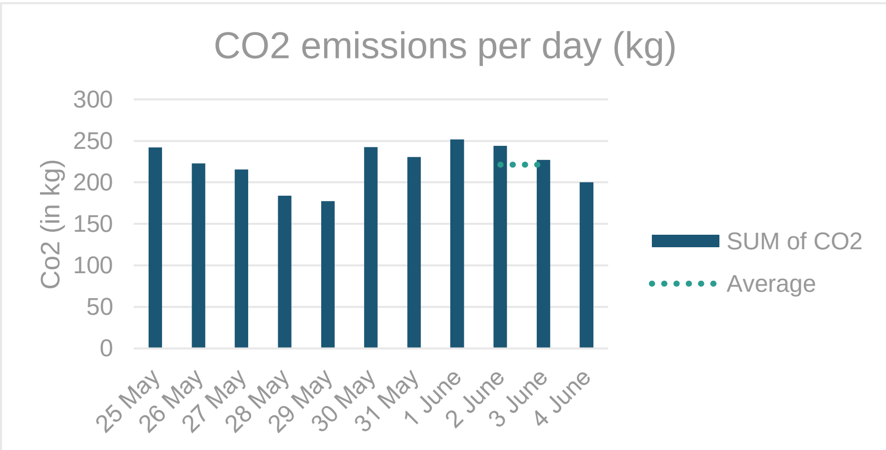

Figure 16: CO_2 emissions per day in KG

Robust data on accidents in the Case Study area could not be provided. Therefore, the number of KSI in the entire Greater Manchester area was chosen as a proxy. A number of 833 KSI casualties were reported for the year 2021[5]. When analyzing DfT data on road safety[6], it can be assumed that 18% of KSI are fatal, assuming that 46 people are killed in traffic in Manchester in 2021.

KPI 4: Changes in behavior

There is no microscopic data available on the modal split within the Case Study Area. As second best, data is available on the entire Greater Manchester area. In 2021, public transport accounts for 5.8% of trips in all of Greater Manchester region (12.5 million PuT trips in total). Active Mobility accounts for 26.6% of all trips[7]. The aim within TANGENT is to increase both shares with 10%, resulting in that from all trips, 50% will be made using sustainable modes.

3.4 Athens

No baseline information on the Case Study in Athens was collected within WP7. This was done because the simulation in WP5 already compares the different scenarios with the baseline scenario developed in WP5. Also, the virtual nature of the Athens Case Study does not relate to the observed data in the real world. Therefore, any variations observed in KPIs that measure traffic performances can never be acknowledge towards TANGENT. Only hypothetical impacts can be determined for the Athens Case Study. More information on the outcomes of the simulation activities in Athens will be given in chapter 4.

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[5] https://democracy.greatermanchester-ca.gov.uk/documents/s22864/GMTC%2022021014%20Road%20Safety%20Update.pdf
[6] https://www.gov.uk/government/statistical-data-sets/reported-road-accidents-vehicles-and-casualties-tables-for-great-britain#all-collision-casualty-and-vehicle-tables-excel-format
[7] https://democracy.greatermanchester-ca.gov.uk/documents/s17105/GMTC%2020211015%20Network%20Performance%20Report.pdf

4 Comparison: Impact of TANGENT

4.1 Rennes

KPI 1: Reducing congestion

Rennes Target: Reducing number of cars by 10% at peak hours.

The main goal for Rennes was to cut the number of cars during peak hours by 10%. But since car numbers alone do not give a complete picture of traffic congestion, also looked at other indicators have been assed, like the average speed of vehicles and how long it took for cars to travel certain routes. In the initial study, conducted from May 10 to May 18, 2023, the average speed on 'rue de Lorient' was between 41.97 km/h and 48.44 km/h, with travel times ranging from 8 to 11 minutes.

After introducing the TANGENT tools in the transport model of Rennes, the indicator changed as followed:

- **Number of Cars** (+9.98%): Instead of seeing a 10% decrease, the number of cars actually went up by 9.98%. This could mean that traffic patterns shifted, with more drivers choosing this route because they thought it would be faster or due to changes on other roads.
- **Average Speed** (Car) (+27.81%): The average speed of cars increased by a notable 27.81%. This implies that, despite more vehicles on the road, the TANGENT tools were effective at improving traffic flow, possibly through better signal timing or routing, allowing cars to move faster.
- **Average Travel Time** (Car) (-32.49%): The average time cars spent traveling dropped by 32.49%, showing that even with more traffic, drivers had quicker trips. This big reduction in travel time could be due to better coordination of traffic or adjustments that reduced bottlenecks, making travelling by car smoother.

Higher intensities and simultaneously a higher traffic flow on the rue de Lorient can be perceived as a discrepancy. However, when having a deeper look at the data this is explained by a higher density of vehicles on the rue de Lorient. Where in the baseline scenario the density was 8.4 veh/km whereas in the optimized scenario it changed to 7.01 veh/km, for overall flow, in baseline scenario it was 3043 veh/h and in optimized scenario it increased to 3039.16 veh/h. This is a 13,88% improvement.

To sum up, while the number of cars on the road was higher than expected. Although the TANGENT tools attract more vehicles to the case study area, the solutions still have a positive effect on traffic flow, shown by faster speeds and shorter travel times. These results show that traffic management solutions within TANGENT boost travel efficiency, even when there are more vehicles on the road, making journeys quicker and smoother through better coordination and optimized infrastructure.

KPI 2: Reducing pollution

Rennes Target: Reducing CO2 emissions by 15% for 2030.

Under KPI 2, Rennes has set a goal to reduce CO_2 emissions on rue de Lorient by 15% by 2030. The baseline study, carried out between May 10 and May 17, 2023, found that the average daily CO_2 emissions were approximately 653 kg. Emissions fluctuated during this period, reaching a peak of 717 kg on May 15, 2023, and a low of 461 kg on May 13. This variation mirrored vehicle flow patterns, with the highest emission days (May 11, 14, and 15) coinciding with the highest traffic volumes, which peaked at 194,410 vehicles per day.

After the introduction of the TANGENT tools, CO_2 emissions during evening peak hours decreased by 5.9%. This reduction indicates that the tools have started to have a positive effect on emissions, likely by improving traffic flow (see KPI 1) and reducing travel times, which could help lower overall CO_2 output even though higher traffic intensities. This proofs that the CO2 reduction caused by traffic flow improvements outweigh the extra emissions caused by more vehicles using the Rue de Lorient. TANGENT has the potential to reduce the amount of CO2 emitted with **38 kg** per day.

KPI 3: Reduction of accidents

Rennes Target: Decreasing number of accidents by 10% for 2030.

The target for this KPI is to reduce the number of accidents in Rennes by 10% by 2030. As of 2023, there were 464 accidents resulting in serious injuries. When analyzing the simulation results, it can be concluded that TANGENT has a minimal effect on road safety. Econometric analysis using simulation output showed that the reduction of accidents caused by TANGENT is between 0 and 1 accident per year.

KPI 4: Changes in behavior

Rennes Targets:

- Reduce 10% share for motorized vehicles.
- From 3% to 9 % for bicycles share.
- From 28% to 35 % for walking.
- From 10% to 15 % for using public transport and increasing the commercial speed to 17 km/h in urban environment and to 30 km/h outside the city.

Assessing behavioral change in the Rennes case study has been proven rather difficult. Results show more car usage (+10%) as well as more public transport users (+17,6%) in the case study area. Unfortunately, in WP3 neither the logit model nor the random forest model provided meaningful results on the background of this new users of the rue de Lorient. This makes it unable to determine whether the new users are people previously using another route (private and public transport users) or that these users made a shift between from one mode to another.

KPI 5: Cooperation with all actors

The aim in Rennes was to create a community of mobility operators via the TANGENT project. The stage 3 workshop of WP1 in Rennes concluded that effective multi-actor collaboration remains a challenge. The project proofed to be good step in the further data and standardization and integration between the different stakeholders involved. However, continuous cooperation is needed to better align decision-making among stakeholders, including public transport operators and the city administration. What needs to be further explored are how to timely share data and which roles the different actors have in the decision-making process.

Overview of Rennes results

KPI Number	KPI Targets	Results
KPI 1	Reducing number of cars by 10% at peak hours (baseline: +/- 162,500)	**+9.98% increase in number of cars** at peak hours. Although the number of cars increased, the TANGENT tools improved traffic flow, leading to faster speeds and shorter travel times.
KPI 2	Reducing CO2 emissions by 15% for 2030 (baseline: average daily CO_2 emissions approximately 653 kg)	**-5.9% CO2 emissions reduction** during evening peak hours, showing positive impact on reducing emissions despite increased vehicle numbers.
KPI 3	Decreasing number of accidents by 10% for 2030 (baseline: 464 accidents in 2023)	**Minimal impact on accidents.** The reduction is between 0 and 1 accident per year, indicating little effect on accident reduction.
KPI 4	Reduce 10% share for motorized vehicles (baseline: share of motorized traffic was 48,5% in 2018)	**+10% increase** in motorized vehicles usage, indicating a shift towards more car usage in the area.
KPI 4	From 3% (baseline) to 9% for bicycle share	**No clear result** available; however, the difficulty in assessing behavior change makes it unclear how this target is progressing.
KPI 4	From 28% (baseline) to 35% for walking	**No clear result available**; similar challenges in assessing this behavior change.
KPI 4	From 10% (baseline) to 15% for using public transport and increasing the commercial speed to 17 km/h in urban environment and to 30 km/h outside the city	**+17.6% increase in public transport use.** Commercial speed increases were likely achieved, although further data is needed to confirm full results for speed improvements.

Table 4: Overview of the results for Rennes

4.2 Lisbon

KPI 1: Reducing congestion

Lisbon Target:

- 10% reduction in person-hours lost due to congestion by 2030.

Since we do not have data on person-hours lost, we make conclusions on congestion, using traffic delays. For Waze, the data shows a large number of delays, with a total of 422 recorded over the observed period. The average delay per incident was 737.9 seconds (approximately 12.3 minutes), while the average speed across all days was 6.7 km/h. For Carris, the total sum of real delays was 946 units over the same period. When considering the overarching goal of reducing person-hours lost due to congestion, the combined data suggest progress towards this goal. While there is no direct measurement of person-hours in the dataset(s), the reduction in average delays and improvements in average speed for Waze indicate progress in mitigating congestion impacts. Carris data, however, points to a need for more targeted interventions, particularly during midweek peaks, to align with the 10% reduction goal by 2030.

KPI 2: Reducing pollution

Lisbon Targets:

- Reducing by 10% the Greenhouse Gas emissions by 2030.
- Reduction of air pollutant emissions (at least 10%) and noise.

While direct emissions and noise measurements are not provided, the traffic statistics offer some insights into trends. Over the observed period in Lisbon, a total of 725,629 vehicles were recorded, with daily averages ranging from 141,452 to 151,992 vehicles. However, without precise emissions data, it is difficult to determine how close Lisbon is to the 10% reduction target. Nevertheless, traffic flow improvements, as reflected in Waze data, may already hint at environmental benefits. Reduced delays and more consistent speeds can lead to lower fuel consumption, potentially decreasing emissions. However, the total vehicle count remains high, indicating that additional TANGENT measures are needed to achieve Lisbon’s ambitious goals.

KPI 3: Reduction of accidents

Lisbon Target:

- Reducing serious injuries in 5% in 2030.

Although Lisbon does not provide direct accident or injury data, indirect indicators suggest progress in creating safer traffic conditions. For instance, the data indicates a reduction in average delay times and more consistent traffic speeds. These factors indicate smoother traffic flow reduces sudden braking and lane changes, which are common causes of accidents. Additionally, reduced delays—averaging 737.9 seconds per incident—suggest fewer instances of prolonged stop-and-go traffic, which can decrease rear-end collisions and other conflicts.

KPI 4: Changes in behaviour

<u>Lisbon Target:</u>

- 7% of public transport increase.

The data show that about 49.2% of the new bus users are former car users (see figure 17). This fact does not cover the whole target, because the public transport sector is broader than busses only. However, we do not have any other available data on other modes of transport. Nevertheless, the large preference of people using the bus instead of the car indicates a positive outcome of the TANGENT tools and a movement towards public transport use.

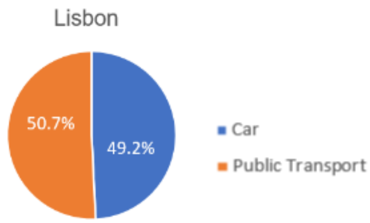

Figure 17: Transport Mode choice percentages under Prioritization to Public Transport scenario for the city of Lisbon

KPI 5: Cooperation with all actors

<u>Lisbon Target:</u> 10% increase in automatically managed incidents with multiple stakeholders.

The stage 3 workshop (under WP1) in Lisbon revealed the importance of data integration for traffic management among different actors. The TANGENT project brought the different stakeholders closer together giving actors insights into one other's data. With the TANGENT dashboard the different stakeholders have am aligned real-time view on the traffic performance. The wish for a further data standardization and integration was expressed at the end of the workshop. The TANGENT project laid the foundation for future cooperation in where incidents are managed automatically with multiple stakeholders involved.

KPI 6: Information for decision-making

<u>Lisbon Targets:</u>

- Inform the public and decision-makers at least on 2 major transport investments.
- Development of a tool to support planning for specific events (planned and unplanned) and simulations for at least 5 planned events.

The TANGENT tools have not yet been used in decision-making processes. This is a direct result of a lack of major transport investment during the implementation phase of the project. On the other hand, with the development of the TANGENT dashboard, a tool has been developed that can support traffic management decision-making during planned and unplanned events. Actors intent to also use the TANGENT dashboard (or similar interface with similar functionalities) in future events.

Overview of the Lisbon results

KPI Number	KPI Targets	Results
KPI 1	Reduce congestion by 10% (person-hours lost) by 2030 (baseline: no data)	**No direct data** on person-hours lost; Waze data shows a reduction in delays and improved speeds, suggesting progress toward congestion reduction.
KPI 2	Reduce Greenhouse Gas emissions by 10% by 2030 (baseline: average value of 1.947 kg CO2)	**No direct emissions data**; traffic improvements suggest potential environmental benefits, but high vehicle count indicates more measures are needed.
KPI 3	Reduce serious injuries by 5% by 2030 (baseline: 7.245 accidents that resulted in serious harm in 2013)	**No direct accident data**; improvements in traffic flow and reduced delays suggest safer conditions, potentially leading to fewer accidents.
KPI 4	Increase public transport usage by 7% (baseline: 22047 bus check ins)	**49.2% of new bus users are former car users**, showing positive progress towards increased public transport use, but broader sector data is unavailable.
KPI 5	Increase cooperation by 10% in incident management with multiple stakeholders	The TANGENT project **successfully brought stakeholders together**, providing real-time data integration for future cooperation, with a focus on further data standardization.
KPI 6	Inform on at least 2 major transport investments and develop a planning tool for 5 events	**No major transport investments** during the project; however, a planning tool (TANGENT dashboard) has been developed to support future event management.

Table 5: Overview of the results for Lisbon

4.3 Manchester

KPI 1: Reducing congestion

TfGM Targets:

- Reduce travel times by 10% at peak hours.
- Decrease speed variability by 10%.
- Improve junction performance by 10% at 10 key junctions.

In Manchester, KPI 1 aims to improve the traffic performance in the case study area, with three key targets: reducing travel times by 10% during peak hours, decreasing speed variability by 10%, and cutting waiting times at intersections by 10%.

The baseline study showed differences in travel times over different days, with the highest being 121 seconds on May 25th and the lowest 89 seconds on May 29th. This shows how congestion varies, with busy days like May 25th and 26th leading to longer trips. On quieter days like May 29th and 30th, travel times were much shorter. One thing that affected travel times during this period was the Elton John concerts at the O2 Arena, scheduled for May 31, June 2, and June 3. The concerts caused travel times to go up by 30% in the area, which shows how important it is to manage traffic well during big events. Although there wasn't specific data on junction performance, data on the travel times gives a good indication that improvements in this area were possible.

Looking at the hypothetical impact of the TANGENT tools, the results show progress toward the KPI 1 targets. Here is how the improvement on indicators look like:

- Travel Time Reduction: 4.73% decrease on regular days and a larger 6.36% drop on days with events. These values are below the desired 10% reduction, but show that TANGENT does contribute to better travel flow in the area.
- Speed Variability: 5.60% improvement on regular days and 9.15% on event days. This means that travel speeds will become more predictable, when implementing TANGENT. TANGENT tools almost meet the beforehand set target of 10% decrease in the speed variability.
- Junction Performance: There was a 13.54% improvement in waiting times at key junctions on normal days, and an even bigger 16.01% improvement on event days. These improvements show that the TANGENT tools will be successful in better handling traffic at busy intersections.

When analyzing the raw values that lay under the KPIs, it shows that the density of vehicles in the area increased by 8.79%, and after optimization the traffic flow increased by 14.19%. Overall, it can be concluded that after implementing the TANGENT tool, the case study area becoming less congested. These effects can be further enhanced when implementing the Dynamic Congestion Pricing (DCP) system. Within the pricing zone, congestion will then be reduced by 64%. Congestion outside the pricing zone will also be decreased by 7% improvement, indicating that the pricing strategy not only benefited the immediate area but also helped to alleviate traffic in surrounding regions.

KPI 2: Reducing pollution and KPI 3: Reduction in the number of accidents

TfGM Target:

- Reduce transport-related CO_2 emissions by 13% per year. TFGM commitment to zero carbon by 2038.
- Reduce 2-5% KSI’s year on year (KSI: killed or seriously injured).

Manchester has set a target to cut transport-related emissions by 13% each year. In the baseline study, done between May 25 and June 4, gives us an idea of where things stand. It showed daily CO_2 emissions ranging from 178 kg to 252 kg. On event days, the average went up to about 221 kg, which is not surprising given the extra traffic generated by the events.

TANGENT can provide a significant contribution to Manchester yearly reduction target. On days without major events, CO2 emissions are expected to drop by 4.2%. On days when there is extra traffic going towards events, CO2 emissions are expected to drop by 2.2%. TANGENT can reduce 9kg of CO2 on normal days and 5 kg CO2 on event days, making a significant contribution to Manchester's city-wide target of 13% CO2 emission reduction per year.

TANGENT also improves the road safety in the case study area. In 2021, it is assumed that 46 people died in traffic in Manchester. Better traffic flows & less speed variation lead to less potential conflicts. Analysis of the model output shows a reduction 6 traffic deaths per year on normal days, and 4 traffic deaths less on event days. EU-wide longitudinal research[8] shows that traffic flow is a predictor for traffic deaths. Traffic flow correlates significant with road deaths, having a correlation coefficient of -49,96. Modelling in Manchester's traffic model shows that TANGENT improves the traffic flow with 13% on normal days and 8,4% on event days respectively. Change in traffic flow multiplied by the coefficient show the decrease of 6 traffic deaths on normal days and 4 traffic deaths on event days. This decrease is an approximate 10% reduction of all traffic deaths in Greater Manchester.

KPI 4: Changes in behaviour

<u>TfGM Target:</u>

- Increase walking and cycling by 10%.
- Increase public transport use by 10%.
    - Supporting the Right mix agenda – 50% of all journeys to be made by sustainable modes by 2040.

Within the optimization of public transport, one of the use cases of TANGENT, public transport offer will be increased by 12,5%. This results in 3,4% more bus-kilometers made by people in the Case Study area. Research in WP3 shows that about 1/3 of these new bus users are former car users (see figure 18). Hypothetically TANGENT can reduce the modal share of private vehicles by 1% and increase Public Transport modal share with 1%. Hereby, TANGENT contributes to the aim of increase public transport use with 10%.

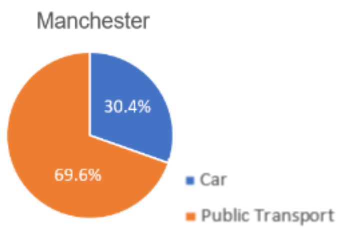

Figure 18: Transport Mode choice percentages under Prioritization to Public Transport scenario in Manchester

[8] https://www.sciencedirect.com/science/article/pii/S0967070X21000731

Overview of Greater Manchester results

KPI Number	KPI Targets	Results
KPI 1	Reduce travel times by 10% at peak hours (baseline: average journey time approximately 105 seconds)	**4.73% reduction** on regular days and **6.36% reduction** on event days. Below the target of 10%, but shows progress in improving travel flow.
KPI 1	Decrease speed variability by 10% (baseline: 32 seconds variability)	**5.60% improvement** on regular days and **9.15% improvement** on event days. Close to the 10% target, showing better predictability of travel speeds.
KPI 1	Improve junction performance by 10% at 10 key junctions (baseline: no specific data on junction performance)	**13.54% improvement** on regular days and **16.01% improvement** on event days in waiting times at key junctions, exceeding the target.
KPI 2	Reduce transport-related CO_2 emissions by 13% per year (baseline: average value of 221 kg CO_2)	**-4.2% reduction** on normal days and **-2.2% reduction** on event days. Reduces CO_2 by **9kg per day on regular days** and **5kg per day on event days**.
KPI 3	Reduce KSI (killed or seriously injured) accidents by 2-5% per year (baseline: 833 KSI casualties in 2021[9])	**Reduction of 6 traffic deaths per year** on regular days and **4 deaths** less on event days, contributing to an approximate **10% reduction** in traffic deaths in Greater Manchester.
KPI 4	Increase walking and cycling by 10% (baseline: no data)	**No specific result.** Based on traffic flow and public transport data, cycling and walking results are not directly measurable from the data provided.
KPI 4	Increase public transport use by 10% (baseline: 5.8% of all trips are public transport related in 2021)	**+12.5% increase in public transport offer**, leading to a **3.4% increase in bus kilometers** and a **1% shift from car use to public transport**.

Table 6: Overview of the results for Athens

[9] No data available for the baseline year

4.4 Athens

KPI1: Congestion reduction

Athens Target:

- Reduce travel times by 10% at peak hours.
- Decrease speed variability by 10%.

Athens aimed to reduce travel times by 10% during peak hours, and the results show that they have surpassed this goal. Total travel time has decreased by 14.33% across all vehicles. The travel time for cars have been reduced by 14.11%. Whereas the total travel time for buses have been reduced by 35.26%. These reductions in travel time indicate that the TANGENT tools for Athens has improved traffic flow, going beyond its initial expectations.

In addition, the second target for Athens was to reduce speed variability by 10% to promote smoother and more consistent traffic movement. Although direct data on speed variability is not provided, there is an increase in harmonic speed—up by 7.63% for all vehicles, 7.53% for cars, and 25.64% for buses. This most probably suggests a more uniform pace of travel, which might have had an effect on the reduction in speed variability.

KPI2: Pollution reduction

Athens Target: Reducing vehicle CO2 emissions by 12% during peak hours.

Athens originally set out to reduce vehicle CO2 emissions by 12% during peak hours, with the goal of improving city air quality and lowering pollution. However, the measurement results for Athens show a 22.65% CO2 reduction, which is nearly double the original target. This positive result may indicate the effectiveness of TANGENT tools in Athens, such as optimizing traffic flow and promoting alternative transportation.

KPI3: Traffic safety

Athens Targets:

- Reduce the number of accidents by 2%.
- Reduce the number of conflicts by 5%.

Athens is focused on improving road safety in its case study area with the goal of reducing the number of accidents by 2% and conflicts by 5%. Regarding traffic flow and conflict reduction, Athens has seen a reduction in overall traffic flow by 7.78%, with a 18.61% decrease in bus flow. Reduced traffic flow generally leads to fewer conflicts, as lower vehicle density and smoother traffic patterns decrease the likelihood of collisions. Additionally, there has been a reduction in lane changes—13.24% overall, and 25.78% for buses—which indicates a corresponding decrease in conflict points. This all in all supports Athens' goal of cutting conflicts by 5%.

As for speed and accident reduction, there has been a 7.63% increase in harmonic speed across all vehicles, with a notable 25.64% increase for buses. This might lead to more consistent speeds, which help avoid sudden stops and risky maneuvers, ultimately reducing accidents. Furthermore, delay times have decreased by 9.19% for all vehicles and by 29.39% for buses, which implies improved traffic efficiency and a reduction in rear-end collisions in high-traffic areas. These aspects contribute to Athens' goal of reducing accidents by 2%. While the primary focus for Athens does not directly target traffic-related deaths, EU studies show that better traffic flow and reduced speed variability enhance road safety, meaning the observed changes in Athens could indirectly reduce serious accidents or fatalities.

KPI4: Modal shift

Athens Targets:

- Increase transit use by 9% on average.
- Decrease car use by 15% in the city center.

Car flow has decreased by 7.68%, which is a step in the right direction, but still far below the 15% reduction goal. Paradoxically, the improvements in car travel times (a reduction of 14.11%) and increased speed (up by 7.53%) may make car travel more attractive, counteracting efforts to shift people toward alternative modes of transport. Additionally, car density has increased slightly by 2.22%, suggesting that reductions in car usage are not substantial enough, particularly in the areas where the changes were most needed. Overall, research on the Athens case shows that 32.6% of the new bus users are former car users (see figure 19).

Furthermore, on the public transport front, buses have seen improvements in performance. Bus speed has increased by 25.64%, and total travel time has decreased by 35.26%, making public transport more efficient and appealing. Additionally, bus frequency has been raised by 12.8%. This fact makes it possible to accommodate more passengers. However, these positive changes are offset by a decrease in bus flow of 18.61% and an increase in waiting times in virtual queues for buses, which have risen by 29.53%. This suggests that capacity may not yet meet the growing demand, limiting the full potential of a modal shift toward public transport. Despite these operational gains, it is unlikely that public transport use has increased by the targeted 9%, as these capacity issues could discourage further uptake.

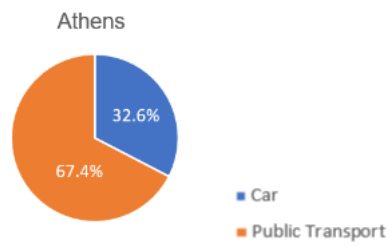

Figure 19: Transport Mode choice percentages under Prioritization to Public Transport scenario for the city of Athens

KPI5: Cooperation of all actors

No data were available on this.

Overview of Athens results

KPI Number	KPI Targets[10]	Results
KPI 1	Reduce travel times by 10% at peak hours	Travel times **reduced by 14.33%** overall, 14.11% for cars, and 35.26% for buses, exceeding the target.
KPI 1	Decrease speed variability by 10%	**Harmonic speed increased by 7.63%** (all vehicles), suggesting reduced variability, though below target.
KPI 2	Reduce vehicle CO2 emissions by 12% during peak hours	CO2 emissions **reduced by 22.65%**, nearly double the target.
KPI 3	Reduce the number of accidents by 2%	Traffic flow and lane changes reduced, likely contributing to **fewer accidents**.
KPI 3	Reduce the number of conflicts by 5%	Fewer lane changes and smoother traffic support **conflict reduction.**
KPI 4	Increase transit use by 9% on average	Transit efficiency **improved**, but bus capacity issues hinder full realization of target.
KPI 4	Decrease car use by 15% in the city center	Car use **decreased by 32.6%**.

Table 7: Overview of the results for Athens

[10] No baseline for Athens

5 Conclusions & Recommendations

5.1 Conclusions

The main finding of the impact assessment is the significant potential effects of different scenarios on travel speed and travel times. TANGENT has a high potential in making dense urban areas more accessible. This potential is high under the regular circumstances, but also during events TANGENT can provide a better utilization of the network. Notably during busier times, the optimization of traffic flows is more challenging, than the times the network is less intensively used.

An important feature of the potential effect of TANGENT is its unintended side-effects. Optimizing traffic flows may persuade car use and can create induced demand in this regard. Road safety is firstly positively impacted by lower speed variation, but when the density goes up, this positive effect becomes smaller. Despite the unintended effects, the positive effects are still stronger. This is evident in the impact of TANGENT on CO2 emissions. Although the induced demand has also been added to the traffic flow, the overall reduction in CO2 emission is positive thanks to better traffic flow and lower waiting times at junctions.

Behavioral change was hard to map within the impact assessment. Therefore, the modal shift that was identified was limited. Both car use and public transport ridership grow when testing the TANGENT use cases in the simulated environment. However, there was limited evidence corroborating car users shifted to public transport.

Cooperation among actors improved in all case studies. TANGENT proved to be a further step in better cooperation and data sharing. More projects are needed to sustain this improved level of cooperation.

5.2 Recommendations

To further test the effects of TANGENT, further pilot testing in other cities is necessary. Only then, it can be concluded to what extent TANGENT can be applied to other cities. Preferably, this further testing should also include real-life pilot testing. In future pilots, TANGENT should also be cross tested in conjunction with other demand management strategies to minimize the effects of induced demand on the optimization of the network. An example of a demand management strategy can be (financial) incentives to generate a modal shift from private transport to sustainable transport options. Additionally, including soft measures related to demand management such as raising awareness campaigns on relevant topics along with providing precise information on availability of alternative transport modes could be effective. A wise collection of pull and push factors can lay the foundation to reach lower car use and more sustainable travel behavior and this collection may vary from one city to the other. Conducting more research is also needed to better understand the profiles of passengers who benefit most from public transport optimization. Furthermore, data can be gathered on a more diverse set of crucial KPIs such as continuous real-time emission, penetration of shared mobility services and micromobility, electrification of the transport system in the city and modal shift also considering other sustainable modes than public transport particularly walking and cycling.

Additional measures are also needed to maximize the positive effects of TANGENT on road safety. TANGENT, on its own, is not enough to improve road safety especially when traffic congestion is sever and there is high likelihood of car accidents on the network.

The impacts of TANGENT may be strengthened also through monitoring KPIs more periodically, during different seasons and in a longer timeframe in every attempt. This can result in gaining more accurate insight into the overall transport ecosystem in the city and assist in conducting more in-depth analysis and discerning the most pivotal areas of improvement.

In the future, efforts on improved data sharing and collaboration in the different case studies will be needed. Establishing data sharing frameworks could happen as part of standardized operational protocols among organizations in charge. This will valorize the increased trust among stakeholders in the TANGENT case studies which needs to be maintained. Besides, the impacts of TANGENT should be continuously assessed. Especially when the tools are actually implemented, it would be of great value to reassess their impacts and compare the results with those of the simulations.