Deliverable 2.2

Specification of the MOMENTUM Test Cases

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Summary sheet

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Abstract	This document is the Specification of the test cases included in the MOMENTUM project: Madrid, Thessaloniki, Leuven and Regensburg. The document defines the scenarios and policies to be considered, the datasets to be used, the novelties evolutions to be implemented in the transport models of the four cities, the KPIs to be analysed, and the stakeholders to be involved in the analysis of the results.
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EMPRESA MUNICIPAL DE TRANSPORTES DE MADRID SA	Spain	EMT
NOMMON SOLUTIONS AND TECHNOLOGIES SL	Spain	NOMMON
DIMOS THESSALONIKIS	Greece	THESS
ETHNIKO KENTRO EREVNAS KAI TECHNOLOGIKIS ANAPTYXIS	Greece	CERTH
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List of acronyms

CAVs	Connected Autonomous Vehicles
D	Deliverable
EC	European Commission
FCD	Floating Car Data
GDP	Gross Domestic Product
GIS	Geographic Information System
GTFS	General Transit Feed Specification
ICT	Information and Communications Technology
ISCED	International Standard Classification of Education
ITS	Intelligent Transport Systems
KPIs	Key Performance Indicators
MaaS	Mobility as a Service
P&R	Park & Ride
SUMP	Sustainable Urban Mobility Plan
UVAR	Urban Vehicle Access Regulations
WP	Work Package

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Executive summary

MOMENTUM takes a wide perspective that includes all the challenges that European cities are facing due to the transformations in urban mobility and an increasingly uncertain future. The project will deliver new methods and tools for mobility data analysis, improved transport models and simulation tools and enhanced decision support tools for urban mobility planning. This wide approach is guided by considering four specific case studies. Each case downscales the challenges associated with new mobility options to the local circumstances of a European city, and provides solutions based on the research conducted in the project. The four European cities are **Leuven** (Belgium), **Madrid** (Spain), **Regensburg** (Germany) and **Thessaloniki** (Greece). This approach guarantees the relevance of the project results, given their heterogeneous characteristics in terms of size, morphology, environmental, socioeconomic and cultural factors, mobility issues and policy goals.

This document provides a comprehensive **definition of the four case studies** that will be deployed in the MOMENTUM project. Each case study description includes an explanation of the **mobility context** of the city, both from a quantitative and from a qualitative perspective. This picture focuses on the emergence of new mobility options in the city and their effects, as well as on the governance and planning context for mobility issues in the city. From this context, the **scope of the case study** is defined, setting up a series of questions to be answered, the time horizon of the analyses, the policies to be tested through the innovative tools and the indicators about the evolution and impacts of new mobility options that the case study is willing to unveil in the local context. The description of the case study includes also the **current status** of transport data sources, modelling tools and their use in the urban policy cycle and transport planning initiatives, in order to define to **which specific aspects MOMENTUM intends to improve**.

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1. Introduction

1.1 Scope and objectives

The overall goal of the MOMENTUM project is to develop a set of mobility data analysis and exploitation methods, transport models and planning and decision support tools able to capture the impact of new transport options and ICT-driven behavioural changes on urban mobility, in order to support local authorities in the task of designing the right policy mix to exploit the full potential of emerging mobility solutions.

The research activities to be conducted in MOMENTUM encompass the development of a conceptual framework for assessing the impacts of new mobility options; the collection and analysis of heterogeneous data sources for characterising mobility patterns; the formulation, calibration and validation of new models capable of capturing the effects of new mobility options; and the development of decision support tools that integrate these data and modelling improvements in the urban policy cycle. These activities are carried out at two levels:

- A general level, where the identification of the main challenges and solutions comes from a Europe-wide perspective.
- A particular level, where the challenges, data sources, analysis techniques, modelling approaches and innovative tools are tailored to the local circumstances of the four MOMENTUM cities: Leuven, Madrid, Regensburg and Thessaloniki.

Each of these four cities host a MOMENTUM Test Case. The objective of this document is to compile the **specifications of the MOMENTUM Test Cases**. The report is the result of the work conducted in part of the WP2 of the project, particularly in the task T2.3 “Specification of case studies”. The aspects covered by this specification are the following:

- **scenarios and policies** to be considered in each city;
- **datasets available** in each city for conducting mobility analyses;
- **novelties and evolutions** to be implemented in the transport models of the four cities;
- **KPIs** to be analysed by transport models;
- **stakeholders** to be involved in the analysis of the modelling results.

1.2 Structure of the document

The document is organised as follows:

- **Section 2 “Leuven”** describes Leuven test case.
- **Section 3 “Madrid”** describes Madrid test case.
- **Section 4 “Regensburg”** describes Regensburg test case.
- **Section 5 “Thessaloniki”** describes Thessaloniki test case.
- **Section 6 “Conclusions”** summarises the research questions included in each case study.

1.3 Reference and applicable documents

Applicable documents:

[I] Grant Agreement No 815069 MOMENTUM – Annex 1 Description of the Action.

[II] MOMENTUM Consortium Agreement, Issue 1, April 2019.

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2. City of Leuven

2.1 City characteristics

2.1.1 City overview

Table 1 – City of Leuven overview

Population	101,695 (2019, Statbel; without unregistered students) - est. 36,000 unregistered students (2019, own estimation; not included in proportions below) 27.4% of inhabitants under 25 years old (2019, Statbel) 16.3% of inhabitants above 65 years old (2019, Statbel) 0.89% of country population (2019, Statbel)
Area	57.51 sq. km
Density	1,768 people per sq. km (without unregistered students)
Average annual precipitation days	135.2 days per year (2016, KMI; ref. period 1982-2010; min. of 1 mm per day) 20.2 days per year (2016, KMI; ref. period 1982-2010; min. of 10 mm per day)
GDP	17,377 million EUR (2017, NBB; nominal) 3.96% of country GDP (2017, NBB; nominal)
Economic sectors	Leuven is dominated by its university, KU Leuven, Europe's most innovative university according to Reuters (2019). Economic activity is fuelled by university spinoffs and large research centres such as the Interuniversity Microelectronics Centre (IMEC) and the university hospital UZ Leuven. The main economic area is consequently research and technology, which accounts for 75% of jobs in Leuven (Statbel, 2016), mainly in electronics, digital technology, healthcare and biotechnology. Traditional industry disappeared in the last few decades, resulting in only 7.5% of the total employment being in the industrial sector, compared to 92% in services (Statbel, 2016). One exception Is InBev, the largest beer brewing company in the world which has its origins and headquarters in Leuven, dominating the north-east of the city. Another important company, both in added value and employment is the Belgian bank KBC, which also has its headquarters in Leuven.
Unemployment rate	6.4% (November 2019, VDAB)
Higher education rate	49% of 25-64 year olds in the province of Vlaams-Brabant have a higher diploma, i.e. ISCED 5 or higher (Statbel, 2018) For Leuven itself, the higher education rate was already 49.9% in the last year with available data (2011, Statbel Census). The same 2011 rate was 38.4% for the province of Vlaams-Brabant. Current higher education rate for Leuven is presumably in the high 50's.

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2.1.2 Mobility overview

Table 2 - Mobility of Leuven overview

Public transport network	Leuven has Belgium's 6th busiest train station, with an average of 33,932 boardings per week day (2018, NMBS). It connects Leuven with all major Belgian cities, including Brussels, Antwerp, Ghent and Liege, with the Leuven hinterland, and also directly with the international airport of Brussels. Local public transport is almost exclusively covered by the public bus company De Lijn. They have a bus fleet of 105 vehicles – 6 of which are full electric (Dec. 2019), – which cover 6.6 million vehicle kilometres per year (2019, De Lijn). Public transport use has grown spectacularly since the 1990s, but in recent years it has experienced a stagnant evolution, as lines and buses are completely saturated.
Active modes infrastructure	About 102 km of the city's total street network of 487 km (excluding motorways) is pedestrianised. However, first and foremost, Leuven is a cycling city. An overwhelming majority of students use cycling as their main mode of transport, resulting in large number of cyclists throughout the city and a high demand for infrastructure. There are over 30,000 bicycle parking spaces, numerous "cycling streets" where cyclists have the right of way and kilometres of bike lanes (providing various levels of separation from motorised traffic). Aimed mainly at commuters, there are "cycling highways" connecting Leuven to Brussels, to smaller cities in the region and to the Leuven outskirts.
Car ownership	822 vehicles per 1,000 inhabitants (2019, Statbel; this number is inflated due to the high number of registered company cars by leasing companies located in Leuven) 505 vehicles per 1,000 inhabitants (2017, estimation based on City Monitor survey)
Total trips per person	On average 2.55 trips per person per day living in Flanders (2017, OVG 5.3) On average 2.39 trips per person per day living in a regional city in Flanders (2017, OVG 5.3; regional cities include Leuven)
Average trip distance	On average 17.80 km per trip by persons living in Flanders (2017, OVG 5.3) On average 32.44 km per trip living in a regional city in Flanders (2017, OVG 5.3) On average 22.0 km per trip to work by people from Leuven (2017, City Monitor)
Modal split	There are several modal split estimations, all of which are imperfect (personal vehicle - public transport - bike/on foot). All trips by persons living in Flanders: 66% - 6% - 28% (OVG 5.3 survey) All trips by persons living in a regional city in Flanders: 59% - 4% - 36% (OVG 5.3 survey) Trips to work by persons living in Flanders: 76% - 8% - 16% (OVG 5.3 survey) Trips to work by persons working in Leuven: 61% - 19% - 19% (Woon-werk survey) Trips to work by persons living in Leuven: 41% - 25% - 34% (City Monitor survey) All trips Leuven: 64% - 12% - 25% (Estimation of Leuven2030 based on data Vlaams Verkeerscentrum, use with care)

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Shared mobility options	Right now, there are only two shared mobility options in Leuven. In the near future, the availability of shared mobility will be higher, fostered by the initiative "mobipunten": numerous locations in the city where public transport and shared mobility options will be combined. Currently, the options are: • **Round-trip carsharing**: many locations, several companies. The two largest providers together had about 3,000 users and 204 cars in 2019, and will expand further in 2020. 4.5 % of Leuven households had at least 1 car sharing membership in 2017. • **Station-based bikesharing**: only one location (train station), one private company, 2,471 active users and 18,365 rides in 2018
CAVs initiatives	-
Urban air mobility initiatives	-
Mobility planning and governance	The **city** is responsible for all local roads and of course developing and implementing local policies, largely based on the Leuven 2030 roadmap which identifies key long-term goals, indicators and actions. See https://roadmap.leuven2030.be/ **AWV (Flemish road administrator)** is responsible for primary roads and highways. **De Lijn (public bus company)** and **NMBS (public train company)** are responsible for public transport planning. The **provincial and regional government** is coordinating interregional mobility planning. Evidently there are several key players that need to be involved in general policy making. Since 2019 there is a new intermediate structure – "**vervoersregio Leuven**" – which formally brings all these stakeholders together for developing an integrated mobility plan for the wider region (+- 500,000 inhabitants) in the coming years.
Mobility culture	Mobility is a highly important issue for citizens. Most cited issues in local surveys are safety, shortage of parking spaces for cars and bikes, congestion and rat running. There are many initiatives from citizens and neighbourhood associations to improve the local mobility situation and to impact the city's mobility policy. This is also illustrated by the willingness of Leuven citizens to participate in citizen science projects like Telraam[1], which is quickly becoming a main source for traffic counts in the context of MOMENTUM. On the other hand, there are also often negative or emotional reactions on mobility related policy change. In the past few years, a circulation plan was implemented in the city centre, with the goal of saving the centre from the grip of drive-through traffic and improving the liveability for citizens and visitors of the city. However, there were and still are a lot of mixed feelings about the new situation, resulting in a lot of

[1] https://telraam.net/en

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	complaints and anger from Facebook groups, even though key performance indicators illustrate a positive improvement overall. While this dissenting group only voices a minority position, as became evident after the last local elections, it is an important and ongoing challenge to get everybody onboard, even though many *Leuvenaars* (the local name for the people of Leuven) are open for new mobility developments. Within Belgium, Leuven is firmly ahead of the curve with regards to adopting new mobility forms, such as car sharing. 12% of the population is already a user of car sharing and 26% is willing to become a user in the near future (City Monitor 2017), resulting in the highest penetration rate in the country.
Mobility policy priorities	Main past initiatives: • **Circulation plan in the city centre**: in 2016 the city centre was divided in several zones, with a large pedestrian zone in the central area of the town. It was forbidden for motorized traffic to go from one zone directly to another. Instead, traffic is guided back to the ringway by so-called "loops" in each zone, with the goal of reducing (through) traffic as much as possible. Main upcoming initiatives: • **Parking plan**: in 2020 a comprehensive parking plan will be developed, based on a new study or parking supply and demand in Leuven. This also includes a coherent strategy for bike parking, which is an ongoing issue for the city as newly added capacity cannot keep up with the ever-growing demand. • **Circulation plans in other city districts**: In the coming years, the outer city districts (Kessel-Lo, Heverlee, Wilsele and Wijgmaal) will get their own circulation plans, regulating traffic flows between the main roads. • **Mobipunten and shared mobility**: to expand the availability of shared mobility and to stimulate the combined use of public transport and shared mobility, the city will install 50 "mobipunten" throughout the city, where several services will be combined (e.g., a bicycle and car-share point installed at train stations). • **Traffic guidance system**: a new traffic guidance system will be purchased and/or developed in the coming years. The first focus is on parking guidance, as our current system is outdated. Later on, the goal is to bring together all kinds of systematic data sources for more general guidance and analysis purposes. • **Regionet**: in the long term, the goal is to develop and overarching, all-encompassing mobility plan for the broader region. The first goals focus on public transport and cycling infrastructure.

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2.2 Scope of the case study

2.2.1 Questions to be addressed

A key objective for the city of Leuven in the MOMENTUM project is the further regional integration of all different transport systems and mobility providers with the future spatial developments. Within this context, it is crucial to have clear insights on future travel behavior and modal shifts. To this end, one of the objectives of Leuven case study is the development of a **new, state-of-the-art, multimodal traffic model**, which also **takes into account all the new mobility providers**.

This multi-modal traffic model will be used to study the impact of planned policies. There are three specific policies that will be analyzed in the case study:

1. The implementation of a **new circulation plan** for districts within the city such as Kessel-Lo and Heverlee.
2. The introduction of 50 so-called '**Mobipunten'**, i.e. small to medium-scale mobility hubs with car-sharing, bike-sharing or scooter-sharing facilities, parking infrastructure and charging stations.
3. The implementation of **Regionet**, a new overarching strategic mobility plan (http://regionetleuven.be/). In particular, the introduction of bus lanes and the implementation of high-quality bike infrastructure, in combination with pricing policies and the implementation of peripheral parking and autonomous shuttle buses will be tested. Regionet will also form the basis for future urban development, such that new developments will be concentrated near public transport hubs.

Regarding these policies, the following questions will be addressed:

1. **Circulation plan:**
   - What will be the effect of the circulation plan on congestion, livability and rat running?
   - Can the circulation plan be further optimized?
   - How much extra traffic on the main roads will be generated by the circulation plan?
   - More specifically, what would be the impact of averting through traffic on certain local roads which have become heavily used transit routes over the years?
2. **Mobipunten**:
   - What is the optimal size of the shared fleet at these 'Mobipunten'?
   - How will they affect car ownership and modal split?
   - How many transfers from one mode to another can we expect at these points?
   - How could subsidies for mode combinations impact this?
   - In a system where shared bikes can be returned to any station; how much intervention would be needed to align asymmetric supply and demand at different locations and at different times (because of large events for example)?
   - Would the related cost be offset by the extra efficiency and use, compared to a system where the shared bike has to be returned to the original station?

3. **Regionet**:

   - To what extent will Regionet contribute to a decrease in the modal share of privately-owned cars, and increase the use of public transport and cycling?
   - Which measures are necessary to ensure accessibility and livability?
   - How large of a modal shift and/or decrease of transport demand is needed to make a large increase of bus traffic on already very congested main roads possible?

2.2.1.1 Time horizons of the analyses

1. **Circulation plan**: both the implementation of a new circulation plan and its effects are expected on a short-term time horizon (1-2 years).
2. **Mobipunten**: the Mobipunten will be implemented during the next 3 years. Its effects are focused on a decrease in private car use and car ownership. These effects take time to become visible. Therefore, a mid-term planning horizon (5-10 years) will be used.
3. **Regionet**: the implementation of Regionet is planned during the next 5 years. Most of its effects are expected to become visible on a mid-term (5-10 years) to long-term time horizon (10-15 years).

2.2.1.2 Policies to be tested

The three policies that will be studied are discussed in section 2.2.1.

2.2.2 KPIs

The following KPI's will be measured for each of the policies:

Table 3 – KPIs to be measured in Leuven case

Case study policy	KPIs
Circulation plan	• Travel times • Queue lengths • Modal share • Traffic flow • Emissions
Mobipunten	• Car ownership • Modal share (including shares of combined modes) • Vehicle kilometres per mode • Usage rate of available supply at Mobipunten
Regionet	• Travel times • Queue lengths • Modal share • Flow • Emissions • Car ownership • Vehicle kilometres per mode • Number of trips

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2.3 Data sources

2.3.1 Usual input data sources in transport planning

Table 4 - Data sources usually employed as input for transport modelling and analyses in Leuven

Data source	Description	Provider	Role
Traffic Data	Traffic counts	City, AWV, Telraam	Non-systematic analyses and evaluations, mostly on a local scale. Example: city centre circulation plan.
Origin Destination Demand	Origin-destination counting	City	Analysing the need for local measures against rat running.
Pedestrian Data	Pedestrian observations	City	Analysing the activity in the shopping areas
Bike-sharing Data Demand	Bike sharing use	City	Analysing the need for additional supply and financial support of shared bikes services.
Telecom data	Mobile phone records	City	Analysing the origin of visitors of Leuven, especially with regards to shopping.
Mobility Surveys	Citymonitor, OVG	City, MOW	Source used to illustrate need and potential for behavioural change
Travel Time Data	Floating car data	City	Analysing congestion

2.3.2 Data sources explored within MOMENTUM case

Table 5 - Data sources to be explored within MOMENTUM project in Leuven

Data source	Description	Provider	Role	Related objective
Public Transport Schedules and Lines	Public Transport Schedules and Lines	De Lijn	Basic information for traffic model	
Transport Network	Transport Network	Internal data	Basic information for traffic model	
Bike-sharing Data Supply	Bike-sharing Data Supply	Bluebikes	Modelling bike sharing supply and demand	Mobipunten, impact on modal share, impact on car and bike parking demand

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Data source	Description	Provider	Role	Related objective
Parking Data Supply	Parking Data Supply	Internal data	Modelling parking supply and demand	
Bike-sharing Data Demand	Bike-sharing Data Demand	Bluebikes	Modelling bike sharing supply and demand	Mobipunten, impact on modal share, impact on car and bike parking demand
Cycling Data	Cycling Data	Internal data, Telraam	Calibrating traffic flows, modal share	All, impact on modal share
Pedestrian Data	Pedestrian Data	Internal data, Telraam	Calibrating traffic flows, modal share	All, impact on modal share
Mobility Surveys	Mobility Surveys	City monitor, OVG Flanders, KULeuven student survey, Woon-Werkverkeer enquête	Modelling mobility behaviour	Mobipunten, impact on modal share, behavioural change
Traffic Data	Data from traffic sensors	AWV, Telraam	Calibrating traffic flows, modal share	All, impact on traffic intensities, modal share.
Parking Data Demand	Parking Data Demand	Internal data	Modelling parking supply and demand	
Land Use Data	Land Use Data	Internal data	Context variable	
Weather Data	Weather Data	Weatherunderground	Context variable	
Social, Cultural or Sportive Events	Social, Cultural or Sportive Events	Uitdatabank	Analysing impact of events on traffic congestion.	Mobipunten, impact of shared mobility on high traffic intensities due to events.
Points of Interest	Points of Interest	Internal data	Context variable	
Demographic Statistics	Census Data	STATBEL	Context variable	Mobipunten, estimate potential for shared mobility
Income statistics	Income statistics	STATBEL	Context variable	Mobipunten, estimate potential for shared mobility
Tourism statistics	Tourism statistics	STATBEL	Context variable	

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Data source	Description	Provider	Role	Related objective
Car Ownership	Car Availability	City monitor	Context variable	Mobipunten, estimate potential for shared mobility
Labour/Unemployment statistics	Labour/Unemployment statistics	KSZ	Context variable	
House price statistics	House price statistics	STATBEL	Context variable	
Business statistics	Business statistics	KBO	Context variable	
Other socio-demographic data	Unregistered students	Internal data	Context variable	
Travel Time Data	Travel Time Data	Internal data	Traffic congestion calibration	Circulation plan, impact on travel times.

2.4 Transport models

2.4.1 Current transport modelling tools

There are two **macroscopic transport models** which involve the city of Leuven and its surrounding region:

- **Provincial model of Vlaams-Brabant**, maintained by *MOW afdeling Beleid*, a Flemish government agency.
- **Macroscopic Dynamic Transport Model for Brussels MDVM** (Macroscopisch Dynamisch VerkeersModel), also maintained by *MOW afdeling Beleid.*

Apart from these macroscopic transport models a **microsimulation of the city of Leuven** is currently being developed by TML commissioned by the Flemish road authority AWV.

2.4.1.1 Provincial model of Vlaams-Brabant

The Provincial model of Vlaams-Brabant is a **multimodal integrated model** for cars, public transport (bus, tram, metro and train), pedestrians and cyclists. Its current version is developed in Cube Voyager. The new version is being developed in VISUM and will be released in 2020.

This model is a **traditional 4-step static, trip-based** multimodal model. The different modes are distinguished in the mode choice model. However, for pedestrians and cyclists there is no network loading component. For public transport, the network loading component is purely timetable based: no interaction with private transport is modelled, and there are no capacity constraints. Finally, the model is non-elastic and there is no departure time choice, meaning that the total number of trips is fixed per time period. The model is **static**, meaning that it uses link cost functions, **without any capacity constraints**. As such, it does not model queue spillback. The route choice generation is explicit. The route choice itself is deterministic.

The calibration is based on traffic counts on both highways and the underlying road network. The mode choice component and the production/attraction component are calibrated based on *Onderzoek VerplaatsingsGedrag*

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(OVG), a large-scale survey on mobility habits, on available census data, and other socio-demographic data. The calibration process mainly focuses on finding a good match with available traffic count data. In the publicly available validation reports this match is expressed by means of the GEH statistic and a t-test. Figure 1 and Figure 2 show the GEH values for morning peak and evening peak models. In literature, a GEH of 5 or lower is considered a good match. One of the reasons why there is a poor match is that many of the traffic count locations are situated on congested segments. With a static model, the flow will typically be overestimated by the model because capacity constraints are not taken into account.

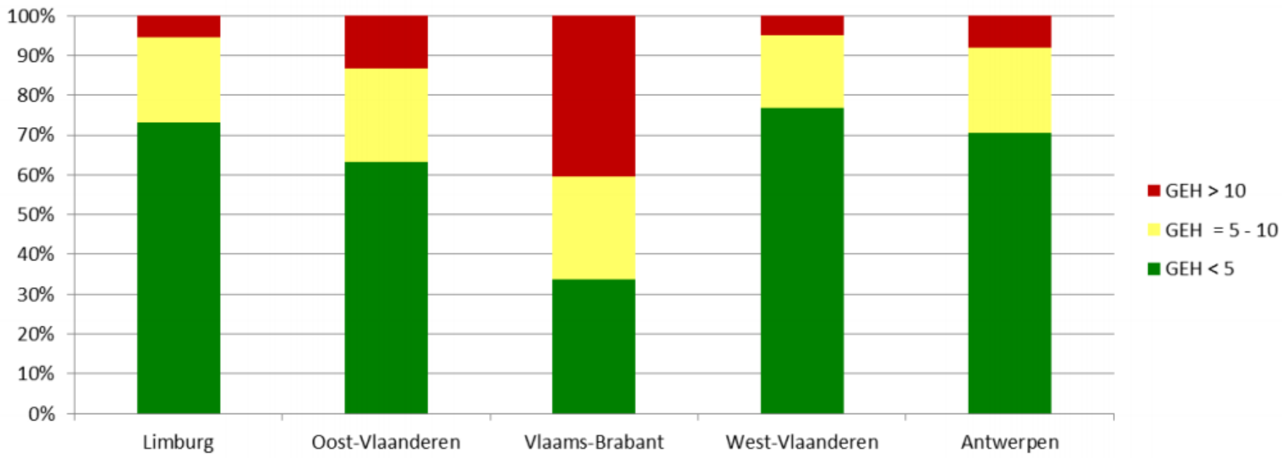

Figure 1 - Morning peak GEH achieved by the provincial model of Vlaams-Brabant. Source: [1]

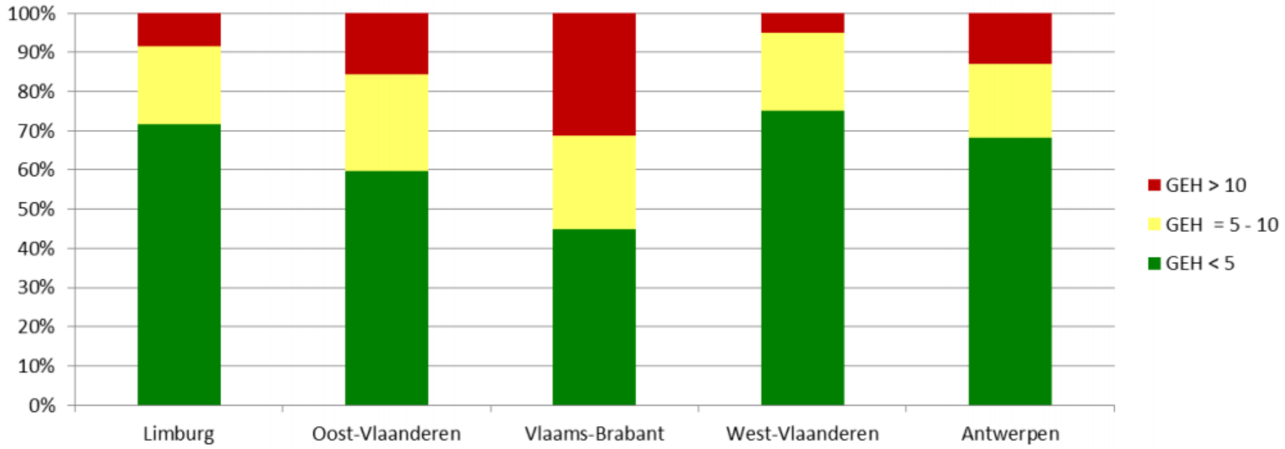

Figure 2 - Evening peak GEH achieved by the provincial model of Vlaams-Brabant. Source: [1]

The main limitations of the provincial model of Vlaams-Brabant are the following:

- It is a **static model**, and therefore cannot capture congestion dynamics. Since the region around Leuven is very congested, this limits the accuracy of the model, and therefore also its applicability.
- **Match with traffic counts**: the flows in the model deviate strongly from available traffic counts. This is partly due to the use of a static model (which inherently causes large deviations on congested highway segments), but also due to a lack of data that was used to calibrate the demand in the model.
- The **level of detail** within a district is not sufficiently good enough to properly evaluate small-scale policies such as the effect of circulation plans, or the introduction of shared-mobility services.
- The modal split in the model is known to be very **insensitive** to changes in costs.

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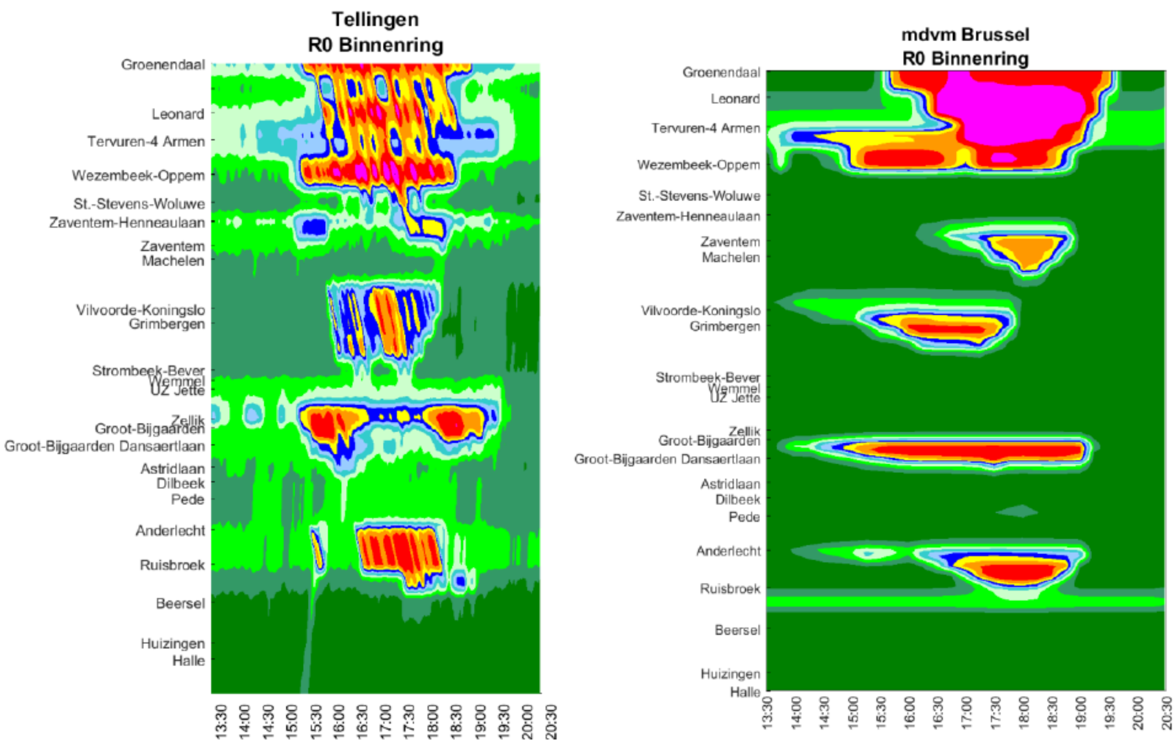
- The model uses a fixed demand to evaluate policies. There is **no induced demand** modelled, and because of the fixed demand, there is a limited sensitivity to pricing policies.
- **Emerging mobility services** are not captured in the model.

2.4.1.2 MDVM Brussels

The MDVM Brussels model is a **motorised private transport model** developed in VISUM.

This model follows a **dynamic** approach based on first-order **Kinematic Wave Theory**. The route choice generation is implicit, and the route choice itself is stochastic, following a logit model. The model is non-elastic and there is no departure time choice, meaning that the total number of trips is fixed per time period by a given dynamic Origin Destination matrix.

The MDVM Brussels is calibrated based on traffic counts, travel time data, and on congestion patterns. Figure 3 shows the match in congestion patterns on the ringway around Brussels in the evening peak.



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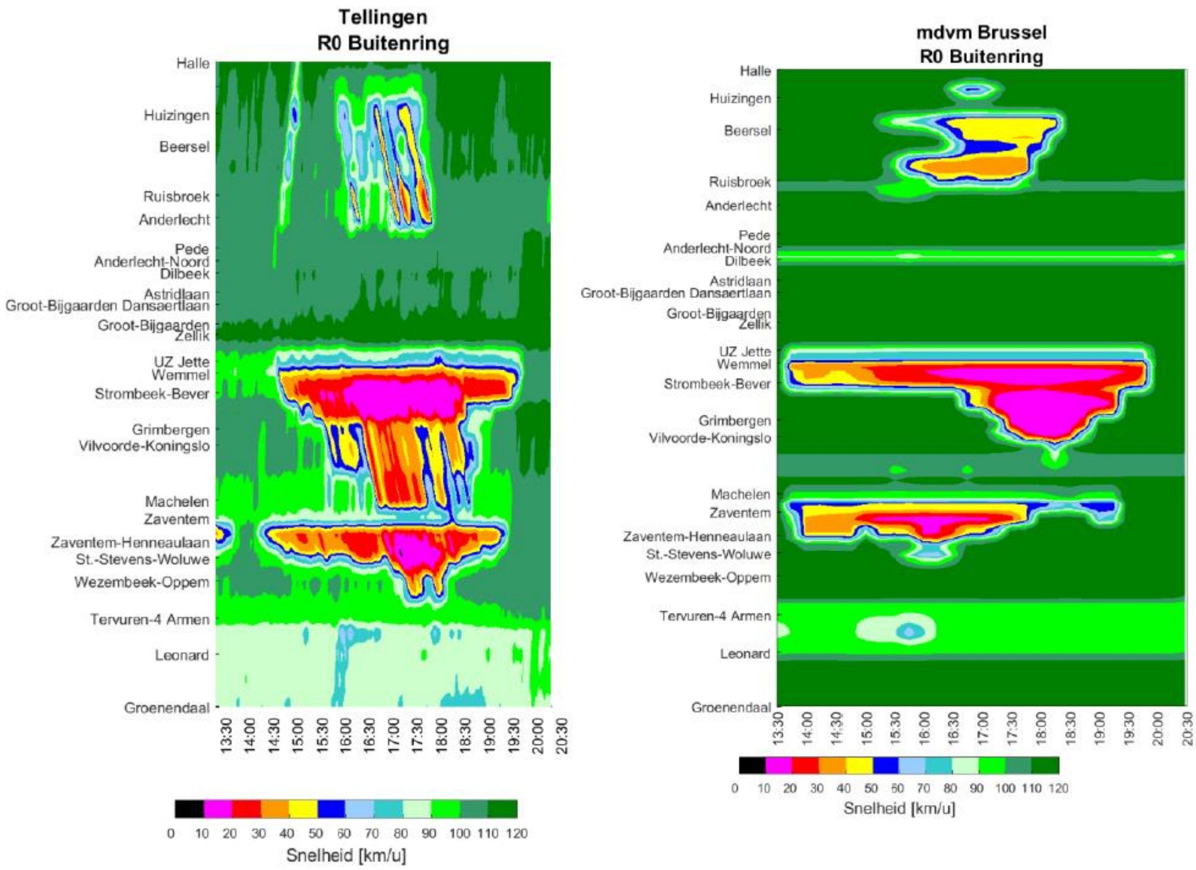

Figure 3 – Congestion patterns across Brussels Ring Road during evening peak (left: traffic counts, right: MDVM model). Source: [2]

Overall, there is a good match in congestion patterns, in the sense that the correct bottlenecks activate in the correct periods of time. Also, for traffic counts there is a good match. The match with the travel times is less accurate for certain highway routes, as the travel time is very sensitive to small deviations in congestion pattern.

The main limitations of the MDVM Brussels model are the following:

- The model is **unimodal**. Policies affecting public transport or bicycle use cannot be evaluated within its framework.
- The model uses a fixed demand to evaluate policies. There is **no induced demand** modelled, and because of the fixed demand, there is a limited sensitivity to pricing policies.
- Only the ringway around Leuven and the main incoming and outgoing roads are modelled. This **level of detail** is not high enough to properly evaluate small-scale policies such as the effect of circulation plans, or the introduction of shared-mobility services.
- The **convergence** of the model sometimes unstable due to the occurrence of gridlock situations.
- **Emerging mobility services** are not captured in the model.

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2.4.1.3 Microsimulation of the city of Leuven

The microsimulation of the city of Leuven is a **multi-class model**[2] as it simulates both cars, public transport, pedestrians and bicycles with specific OD matrices. However, it is not a multimodal integrated model as there is no mode choice between these different modes. The model is being developed in VISSIM. This model follows a **dynamic microsimulation** approach. The route choice is fixed, so there are no rerouting effects. Also, the number of trips per time period is fixed. The microsimulation of the city of Leuven is calibrated based on traffic counts and split rates. There is a good match with reality.

The main limitations of the microsimulation of the city of Leuven:

- The model is **unimodal**. Policies affecting public transport or bicycle use cannot be evaluated within the model.
- The microsimulation uses split fractions. As such, **no rerouting** can be modelled.
- Only the ringway around Leuven and the main incoming and outgoing roads are modelled. This **level of detail** is not good enough to properly evaluate small-scale policies such as the effect of circulation plans, or the introduction of shared-mobility services.
- The model uses a fixed demand to evaluate policies. There is **no induced demand** modelled, and because of the fixed demand, there is a limited sensitivity to pricing policies.

2.4.2 Transport modelling innovations within MOMENTUM case

The objective of the case study is the development of a new, state-of-the-art, multimodal transport model which also considers all new mobility providers. This transport model **will start from the Provincial model of Vlaams-Brabant**. Therefore, we compare the novelties that are necessary to answer the questions in section 2.2 with the Provincial model:

- **Inclusion of emerging mobility services**: in the policy about 'Mobipunten' (and in Regionet to a lesser extent) shared mobility plays a crucial role. These mobility services need to be modelled in order to potentially evaluate their effect.
- **Model for car ownership**: both in the policy about 'Mobipunten' and Regionet the effect on car ownership is seen as a crucial element. Current models take car ownership as a given, or as an external input. One of the novelties of the new model is therefore to consider the relationship between the availability of shared-mobility services and car-ownership.
- **High level of detail on district level**: the current match between modelled and actual traffic flows is not sufficient to be able to conduct analyses within a district. One of the novelties in the case study is the large-scale availability of traffic counts on micro-level, that is unique for state-of-the-art transport models. This data will be used to calibrate the new model. It will lead to a better match and allow analyses of circulation plans and other local policies.
- **Inclusion of induced demand**: the current model uses a fixed number of trips and does not consider the possibility of not making a trip. The new model will include this possibility. This will allow pricing policies (e.g. parking policies) to be modelled properly. It also allows to evaluate the effect on accessibility, as, e.g., exuberant congestion can lead to a decreased demand.

[2] 'Multi-class' models deal with more than one transport mode but with independent OD matrices, while 'multimodal' models simulate trip chains performed in more than one transport mode.

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2.5 Integration of transport models in the urban policy cycle

2.5.1 Current integration mechanisms

The **Provincial model of Vlaams-Brabant** is occasionally used to assess the impact of a proposed measure on traffic flows. However, this use is limited because of:

- User unfriendliness of the model, as the users have to make requests to the regional government managing the model, in a tedious, "bureaucratic" way.
- Low confidence in the model results by most stakeholders. Even for main roads, results are usually met with a lot of scepticism.
- Not really usable for analyses when local level roads have to be included.

The **microsimulation of Leuven** is sometimes used to assess the impact of a proposed measure, mainly to check the effects on congestion. There are a number of limitations:

- The model typically works with fixed route choice. This makes it difficult to use in scenarios which have a large impact on rerouting.
- The model works with fixed demand. As a result, future scenarios typically use a demand that is determined outside the microsimulation (e.g. Provincial model). This makes it difficult to assure consistency between the demand determined outside the microsimulation, and the results of the microsimulation which would cause a different demand and/or routing.
- The amount of effort to develop this model is large.

Because of these limitations, microsimulation is usually limited to relatively small, operational, supply-side policies with a short planning horizon.

2.5.2 Transport models integration initiatives within MOMENTUM case

The model **should be made available and accessible** for a city advisor with a reasonable level of expertise, if necessary, a short introduction and info-session should be organised to transfer know-how and experience to the users. The following aspects will be considered:

- Support the expertise building within the city's mobility department, provide consultation if required, and offer future updates and timely calibration efforts as a potential service.
- Focus on openness, user-friendliness (to a point) of the model. Do not lock it in at an external partner.
- Support engagement process: develop inclination to use simulations, develop a sense of ownership regarding this kind of analyses. To achieve this, illustrate the potential of the model to the city via various projects, and support the city in using the model on their own, so that the trustworthiness and credibility on the model increases.

There are some issues that will need specific assessment during the integration of the tools developed within MOMENTUM case:

- At least 1 year of real experience is required, so it is essential to communicate the potential benefits of using the model, so to justify the time and financial investment requirement.
- The achievement of appropriate accessibility standards: openness and user-friendliness.

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- The availability of resources for performing the model calibration. This requires extra budget, so the city must be prepared to include this in their medium-to-long-term planning.
- The linkage to potential new data that become available. This can be managed by ensuring that the model uses open data standards.

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3. City of Madrid

3.1 City characteristics

3.1.1 City overview

Table 6 – City of Madrid overview

Population	3,226,126 (municipality, INE, 2019) – 6,662,000 (Madrid region, INE, 2019) 22.7% of inhabitants under 25 years old (municipality, INE, 2019) - 15.5% of inhabitants under 25 years old (Madrid region, INE, 2018) 20.2% of inhabitants above 65 years old (municipality, INE, 2019) - 17.5% of inhabitants above 65 years old (Madrid region, INE, 2018) 7% of country population (municipality, INE, 2019) - 14% of country population (Madrid region, INE, 2019)
Area	605.77 sq. km (municipality) 8,022 sq. km (Madrid region)
Density	5,325.66 people per sq. km (municipality) 830 people per sq. km (Madrid region)
Average annual precipitation days	84 days per year (2018, AEMET; ref. period 1950 - 2018) 80 days per year (2018, AEMET; ref. period 2009 - 2018)
GDP	144,265 million EUR (municipality, 2018) - 230,795 million EUR (Madrid region, 2018) 12% of country GDP (municipality, 2018) - 19.2% of country GDP (Madrid region, 2018)
Economic sectors	Tertiary activities accounts for 88% of the GDP. The city concentrates the most prominent companies in many economic sectors. Indeed, the following sectors have more than 30% of the Spanish companies located in the city (Madrid City Council, 2019): • Financial, investment funds and insurance • Telecommunications • Software development and technological consulting • Cultural and editorial industries • Freight and logistics
Unemployment rate	10.3% (municipality, 2019) - 13.8% (Madrid region, 2017)
Higher education rate	47% (25-64 years old, Madrid region, Eurydice, 2017)

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3.1.2 Mobility overview

Table 7 - Mobility of Leuven overview

Public transport network	Madrid has a wide public transport network that covers all the region municipalities. In the inner city, the system is based on a Metro system with 13 lines and 236 stations and on the urban bus network, which has 212 lines and 4.100 stops (EMT Madrid, 2020). The metropolitan area is served by a commuter railway network with 9 lines and 94 stations; and by the metropolitan bus network, which has around 450 lines and more than 8,000 stops. The overall public transport network length is 11,000 km.
Active modes infrastructure	Madrid cycling network is composed of 349 km of dedicated lanes (Madrid City Council, 2020). Among these lanes, it has to be taken into account that the Green Cycling Belt, a recreational cycle path that connects green areas in the outskirts, has a length of 67 km. A network of sharrows, i.e. shared lanes with cars with a 30 km/h speed limit, complements this dedicated network, with a length of 346 km (Madrid City Council, 2020). The central district of the city has many pedestrianised spaces.
Car ownership	384 vehicles per 1,000 inhabitants (municipality, OMM, 2017) - 530 vehicles per 1,000 inhabitants (Madrid region, OMM, 2017)
Total trips per person	2.4 trips per person (municipality, EDM2018, 2020)
Average trip distance	6 km (municipality, EDM, 2004)
Modal split	In Madrid city (2012): Private vehicle: 29% Public transport: 42% Walking & cycling: 29% In the region (EDM2018, 2020): Private vehicle: 39% Public transport: 25% Walking & cycling: 32.1% Other modes: 3%
Shared mobility options	• **E-hailing**: two companies at the moment and around 8,500 licences • **Round-trip car-sharing** • **One-way carsharing**: five electric car sharing providers with more than 2,600 electric cars • **Station-based bikesharing**: BiciMAD, owned by the municpality and managed by EMT, with around 2,500 vehicles and 207 stations. • **Free floating bikesharing**: one provider • **Motosharing**: six electric motosharing providers with almost 5.000 e-motorbikes • **Scooter sharing**: 16 companies and around 5,566 e-scooters licences The station-based bikesharing system is public, the others are all private.
CAVs initiatives	**SHOW**. H2020 EU funded project which aims to support the migration path towards affective and persuasive sustainable urban transport, through technical solutions,

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	business models and priority scenarios for impact assessment, by deploying shared, connected, cooperative, electrified fleets of autonomous vehicles in coordinated Public Transport (PT), Demand Responsive Transport (DRT), Mobility as a Service (MaaS) and Logistics as a Service (LaaS) operational chains in real-life urban demonstrations in 5 Mega, 6 Satellite and 3 Follower Pilots taking place in 20 cities across Europe. By deploying a fleet of all types (buses, shuttles, pods, robo-taxis, automated cars connected with MaaS and cargo vehicles) and for all transport operators (passengers, cargo and mixed transport) in both dedicated lanes and mixed traffic, connected to a wide range of supporting infrastructure (5G, G5, IoT, etc.) and operating under traffic speeds ranging from 18 to over 50 km/h. It is user-led (by UITP) and realised by a Consortium of 69 Partners, 6 third parties and with the additional support of 60 stakeholders (connected through LoS, including major stakeholder Associations) and twinning actions with 11 organisations the US, S. Korea, Australia, China, Taiwan and Singapore. Madrid partners (Tecnalia, EMT, Irizar and Indra) will carry out the following demos: Seamless autonomous transport, AD and teleoperation, Convoy and platooning, Autonomous docking and parking applications and Self-learning DRT. The project started January 1st, 2020 and will last for 48 months. **AUTO-BUS**: Project funded by CDTI (Spanish Centre for the Development of Industrial Technology). The project addresses the safe and efficient automation of urban buses for their operation in the warehouses and depots to facilitate the tasks of refuelling, washing, movements to workshops and parking, with a direct impact on the company's operations (saving time, space, etc...). The demonstrator would use a Gulliver e-minibus and it would be carried out at the Carabanchel operations center, whose configuration follows the most frequent guidelines in modern warehouses. The project will be developed by EMT in conjunction with INSIA (the University Institute of Automobile Research, belonging to Technical University of Madrid) and CSIC (Spanish National Research Council, specifically CAR Automation and Robotics Center). The project is about to start shortly (1st quarter 2020).
Urban air mobility initiatives	The City Council has collaborated in research proposals for the evaluation of Urban Air Mobility impacts in the city.
Mobility planning and governance	• The **Madrid Region Transport Authority** (Consorcio Regional de Transportes de Madrid, CRTM: https://www.crtm.es/) is the main responsible for public transport planning within the city and the region. • Traffic planning and the Taxi service inside the city area correspond to the **City Council** (https://www.madrid.es/portal/site/munimadrid). • There is a **SUMP** (2014-2020), which is under revision, and with the aim of developing a new one. The Quality Air Plan "**Plan A**", approved by the last local government, is still in force. The new local government has presented their new plan "**Madrid 360**" in 2019.
Mobility culture	Mobility planning has been a central issue in the last electoral campaigns. The aspects that raise more public discussion were the implementation of low emission zones and the traffic restrictions applicable during high pollution episodes.

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	According to municipal surveys, 3 out of 5 main problems of the city are related to mobility, only surpassed by street cleaning: air pollution, traffic congestion and sidewalks quality (Madrid City Council, 2018). The latest municipal survey related to the Urban Vehicle Access Regulation zone set up in 2018 (called Madrid Central) reveals that more than 50% of the citizens would disagree with the re-opening of the main street affected by this zone to all vehicles (Madrid City Council, 2019). The proliferation of shared electric vehicles on the streets, especially e-scooters, has opened a debate about the use of public space, since this is sometimes troublesome for the most vulnerable street users. The use of ride hailing services has also increased within the last years.
Mobility policy priorities	The **reduction of air pollution** caused by private car traffic has been a policy priority. In the recent years, a Low Emissions Zone has been set in the central district, with Urban Vehicle Access Regulation. Within this area, only residents, electric or eco vehicles and those who are going to use an off-street parking can drive. In addition, the bus fleet has been partially renewed and many sharrows have been introduced, in order to contribute to traffic calming. The current local government have launched the environmental sustainability strategy "**Madrid 360**", in order to meet air quality requirements. This plan Intends to intensify the bus fleet renewal, by Introducing more electric buses, and reinforces the access restrictions to the central district by forbidding the entrance of the most pollutant vehicles. In addition, the municipality is promoting new parking facilities and Park&Ride schemes.

3.2 Scope of the case study

3.2.1 Questions to be addressed

The main goal of Madrid case study is to **include shared mobility** impacts in the transport planning and decision-making processes. This will be done through the development of new analytical solutions that will complement and enhance the existing multimodal macroscopic transport model developed by EMT Madrid. The focus of the case study will be on the effects that shared mobility has in the travel demand patterns across the city and on the implications for EMT Madrid as a major public transport operator in the city.

The case study will use three types of city areas to perform the analyses, targeting different questions:

- **MOMENTUM Lab 1 - Central district**. This area is chosen because is the one where shared mobility operators are present since their arrival to the city, and also because is the one where a Low Emissions Zone has been implemented, including an Urban Vehicle Access Regulation area. This will allow us to analyse **to what extent is shared mobility used as a substitute to private car trips**, in relation to the implementation of these policies.
- **MOMENTUM Lab 2 - Districts where shared mobility services have been recently implemented**. These areas are chosen because they have different demographic and social structures, in terms of age, income, etc. between them and with the Central district. It is not enough explored **to what extent is shared mobility accessible to all citizens.** The comparison of use and adoption patterns in different areas will

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allow us to develop insights about this issue. Also, these areas have a lower public transport density and, therefore, it seems shared mobility can play an important role as complementary to public transport.

- **MOMENTUM Lab 3 - Districts where shared mobility has not been yet implemented**. There are a number of peripheral districts without any shared mobility supply at the moment. It is still unclear if public authorities could promote the implementation of these services as a tool for first and last mile complementarity with public transport services. Therefore, the research question related to these areas is: **To what extent shared mobility services can improve public transport accessibility by complementing it?**

Figure 4 shows the districts which could host these three urban laboratories to explore the addressed questions.

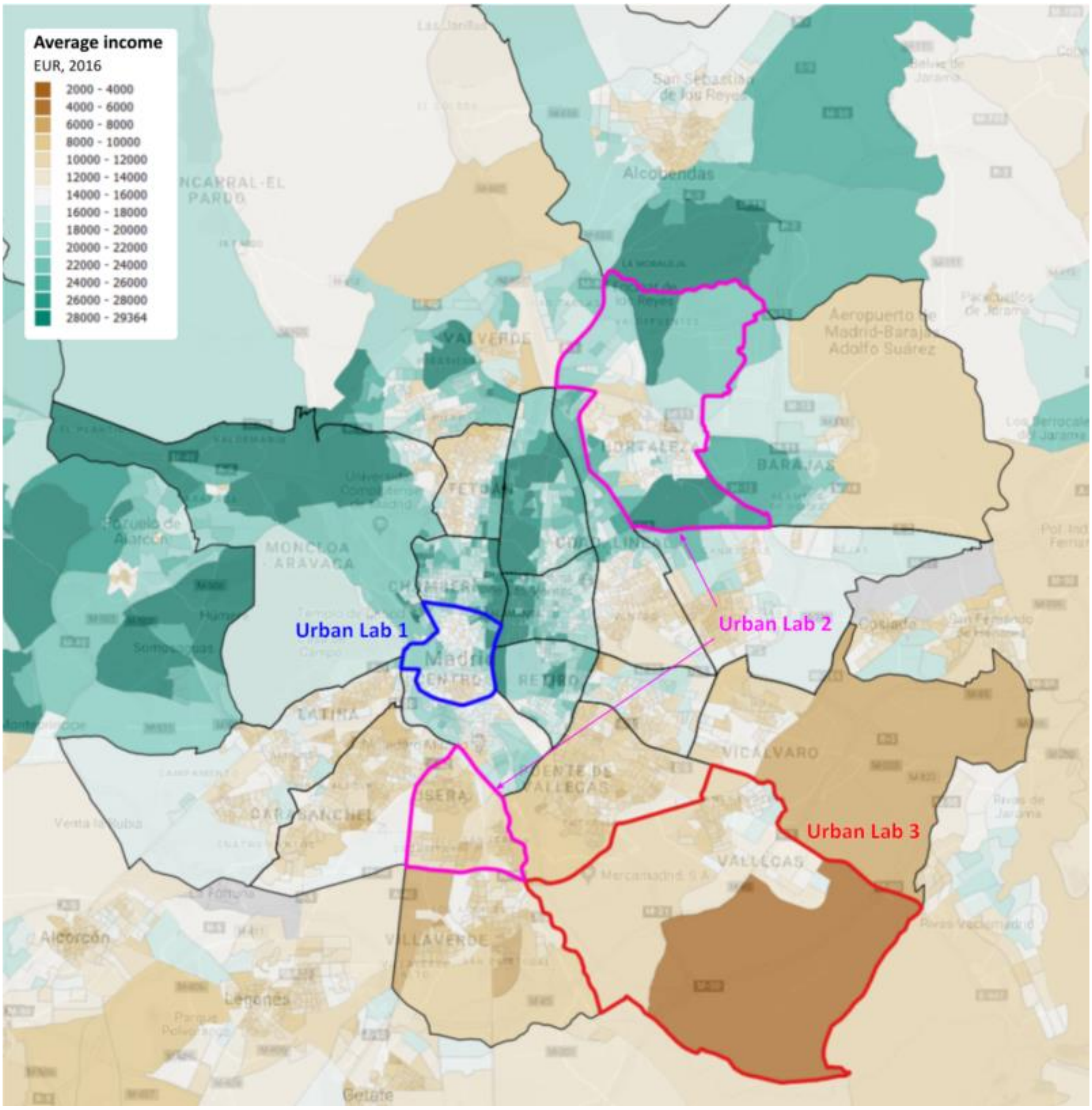

Figure 5 – Tentative locations for the three urban laboratories used in the Madrid study case

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3.2.1.1 Time horizons of the analyses

The case study will deal with two separate time horizons: **2025** and **2030**. The first time horizon will be adapted to the scope of the incoming urban mobility plan. The furthest horizon will serve for developing a set of explorative scenarios that provide insights about how different shared mobility configurations may have an effect on the city and on the bus network.

3.2.1.2 Policies to be tested

There are two types of policy implications for the case study:

- **Interaction between shared mobility and private car restrictions**. The inclusion of shared mobility modes in the transport model of the city allows planners to take into account this mode when testing the modification of current Urban Vehicle Access Regulation zones or the effects of different emergence protocols for high pollution episodes.
- **Public incentives and/or regulatory schemes for shared mobility services**. The conclusions about the equity of shared mobility services and the complementarity with public transport are useful for defining the most appropriate collaboration framework between operators and the city administration.

3.2.2 KPIs

There are a set of KPIs that are related to each question to be explored:

1. **To what extent is shared mobility used as a substitute to private car trips?**
    - Modal share of shared mobility services
    - Trip induction of shared mobility services
    - Modes previously used by shared mobility users.
    - Shared mobility trips recurrence.
    - Shared mobility trips distances.
2. **To what extent is shared mobility accessible to all citizens?**
    - Age distribution of shared mobility users.
    - Income estimated distribution of shared mobility users (e.g. through home location).
3. **To what extent shared mobility services can improve public transport accessibility?**
    - Door-to-door public transport travel times before and after the introduction of complementary public transport services.
    - Fleet size and shared mobility service configuration needed for contributing to public transport use.

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3.3 Data sources

3.3.1 Usual input data sources in transport planning

Table 8 - Data sources usually employed as input for transport modelling and analyses in Madrid

Data source	Description	Provider	Role
Public Transport Schedules and Lines	Public transport supply information	EMT, Madrid Regional Transport Consortium	Introduction of public transport services in the transport model
Transport network	Road and railway infrastructures	HERE Network. Q4-2016	Introduction of transport network in the transport model
Parking Supply Data	All on-street parking and off-street parking managed by EMT or Madrid City Council	Madrid City Council, EMT	Dummy variable in modal choice model
Public Transport Smart Card Data	Smart card data from public transport services	EMT	Analysis of public transport trips generation and distribution to segment OD matrices from telecom data
Mobility Surveys	Available household travel surveys for the Madrid region (2004, 2014)	Madrid Regional Transport Authority	Analysis of modal split
Telecom Data	OD matrices for different periods of 2017, obtained from Telecom Data. Anonymised mobile phone records	Orange, processed by Nommon	Analysis of trip generation and distribution
Traffic Data	Data from traffic sensors	Madrid City Council	Route assignment calibration in travel demand modelling
Land Use Data	Distribution of land uses across each transport zone	SIOSE, Madrid City Council	Improve the spatial precision of telecom data and characterise transport zones (generation and attraction potential)

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Data source	Description	Provider	Role
Points of interest	Distribution of points of interest	Madrid City Council	Characterise transport zones (attraction potential)
Demographic Statistics	Population census by tract segmented by several sociodemographic variables	Madrid City Council	Population and sociodemographic variables of each transport zone, used for sample expansion of telecom data and mobility surveys; and for travel demand modelling parameters
Travel times data	Travel times between transport zones	City Council models, EMT, Madrid Region Transport Authority	Include travel times in different transport modes to the model

3.3.2 Data sources explored within MOMENTUM case

Table 9 - Data sources to be explored within MOMENTUM project in Madrid

Data source	Description	Provider	Role
Car/Moto-Sharing Data Supply	Data from moto-sharing service	Several service providers	Add carsharing/motosharing supply to transport models
Bike-sharing Data Supply	Stations data from public e-bike sharing service (BiciMAD)	EMT	Add bikesharing supply to transport models
Cycling Data	Cycling counts	Madrid City Council	Add cyclists flow measurements to transport models
Pedestrian Data	Pedestrian counts	Madrid City Council	Add pedestrian flow measurements to transport models
Mobility Surveys	New household travel survey for the Madrid region (2018)	Madrid Regional Transport Consortium	Update inputs from previous mobility survey and addition of new variables explored in the latest survey

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Data source	Description	Provider	Role
MaaS Demand Data	Data from EMT MaaS mobile app	EMT	Add shared mobility services usage and adoption patterns to transport models, with particular focus on the multimodal use of these services
Car/Moto-Sharing Demand Data	Data from moto-sharing service	Several service providers	Add carsharing/motosharing demand (generation, distribution and user profiling) to transport models
Parking Demand Data	Off-street parking managed by EMT	EMT	Introduction of parking demand information to transport models
Weather data	Weather variables that may be relevant for mobility patterns	AEMET	Analysis of the influence of weather variables on the use of bikesharing and motosharing services
Land Use Data	Neighbourhood characterisation by land use and activities	Madrid City Council	Analysis of the influence of commercial and other specific land uses on the use of shared mobility services
Income statistics	Income data for each transport zone	INE, Madrid City Council	Analysis of the influence of income levels on the adoption of shared mobility services
Tourism statistics	Supply and demand information of tourism in the city	Madrid City Council	Analysis of the influence of accommodations location in the spatial use patterns of shared mobility services
Business statistics	Location of business places	Madrid City Council	Analysis of the influence of business location in the spatial use patterns of shared mobility services
Car Ownership	Car ownership data for each transport zone	Madrid City Council	Analysis of the influence of car ownership levels on the adoption of shared mobility services
Travel times data	Travel times between transport zones	Google Maps, Open Street Maps	Analysis of the effects of accessibility differences between private vehicles and public transport in the use of shared mobility services

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3.4 Transport models

3.4.1 Current transport modelling tools

At the moment, there are three public administrations maintaining and using transport models in the metropolitan area:

- **Madrid Region Transport Authority**. This institution has a multi-class macroscopic model developed in EMME. It includes the whole public transport network of both Madrid city and region (CRTM, 2004). This model is used for transport planning purposes.
- **Madrid City Council.** The Mobility Department of the City Council maintains a macroscopic model in TransCAD and performs microscopic simulations in Aimsun for certain interventions.
- **Madrid Municipal Transport Company (EMT).** EMT has developed an **integrated multimodal macroscopic model** in PTV VISUM software. Taxi is included as a mode but no information is available at the moment. Motorbike and car are defined as different modes but at this moment demand is not differentiated. The road network includes the whole network of the region, including paths not suitable for motor vehicles. The area is divided into 1,259 zones, using the same zoning of the last mobility survey carried out by the Transport Authority of the region. Demand is considered for four different periods of the day (morning peak hour, midday peak hour, evening peak hour and off-peak), different types of day (labour, Fridays, Saturdays and Sundays & holidays) and different periods of a year (winter, summer and midterm). The reference year is 2018. The model is currently under calibration, using several types of data: traffic counts, ticketing data in subway and railway stations, and bus users per line and period. Figure 6, Figure 7 and Figure 8 show the networks involved in the project.

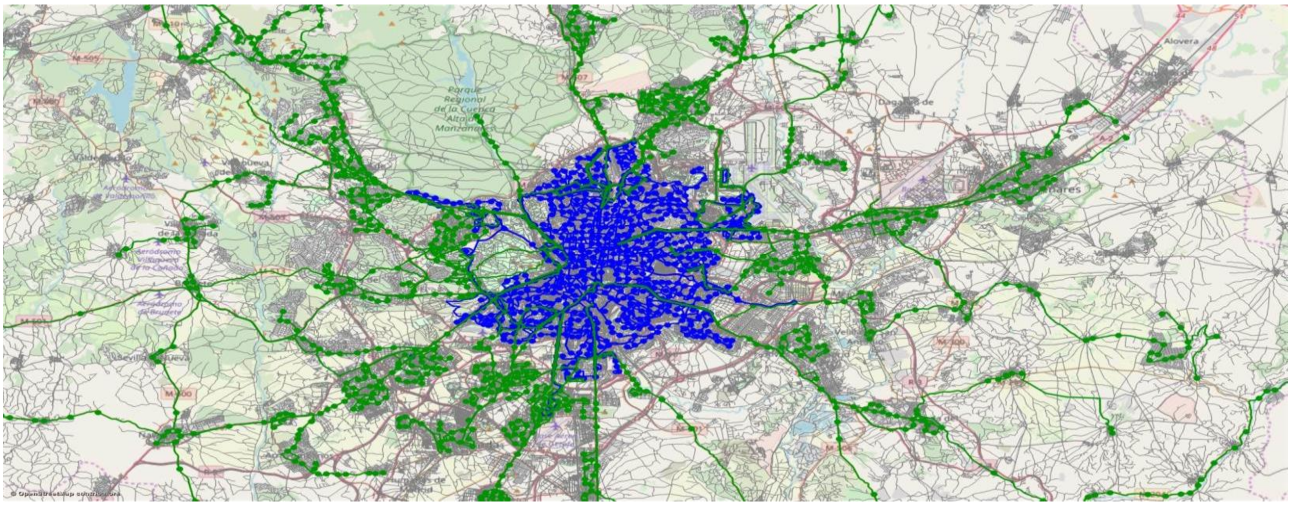

Figure 6 – Madrid bus network in the EMT Madrid model

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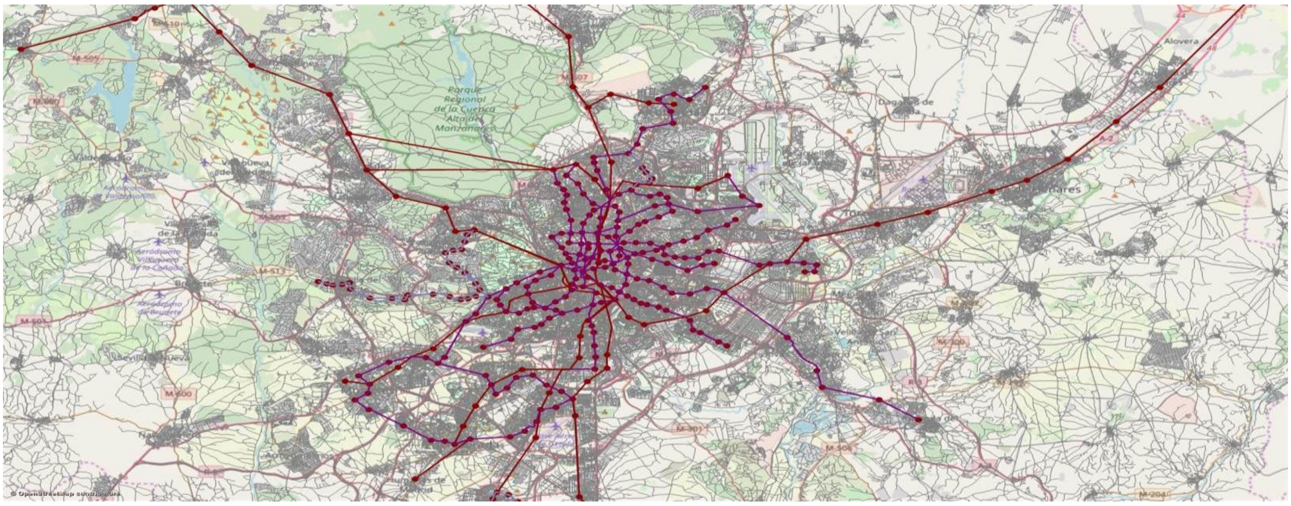

Figure 7 – Madrid railway and metro network in the EMT Madrid model

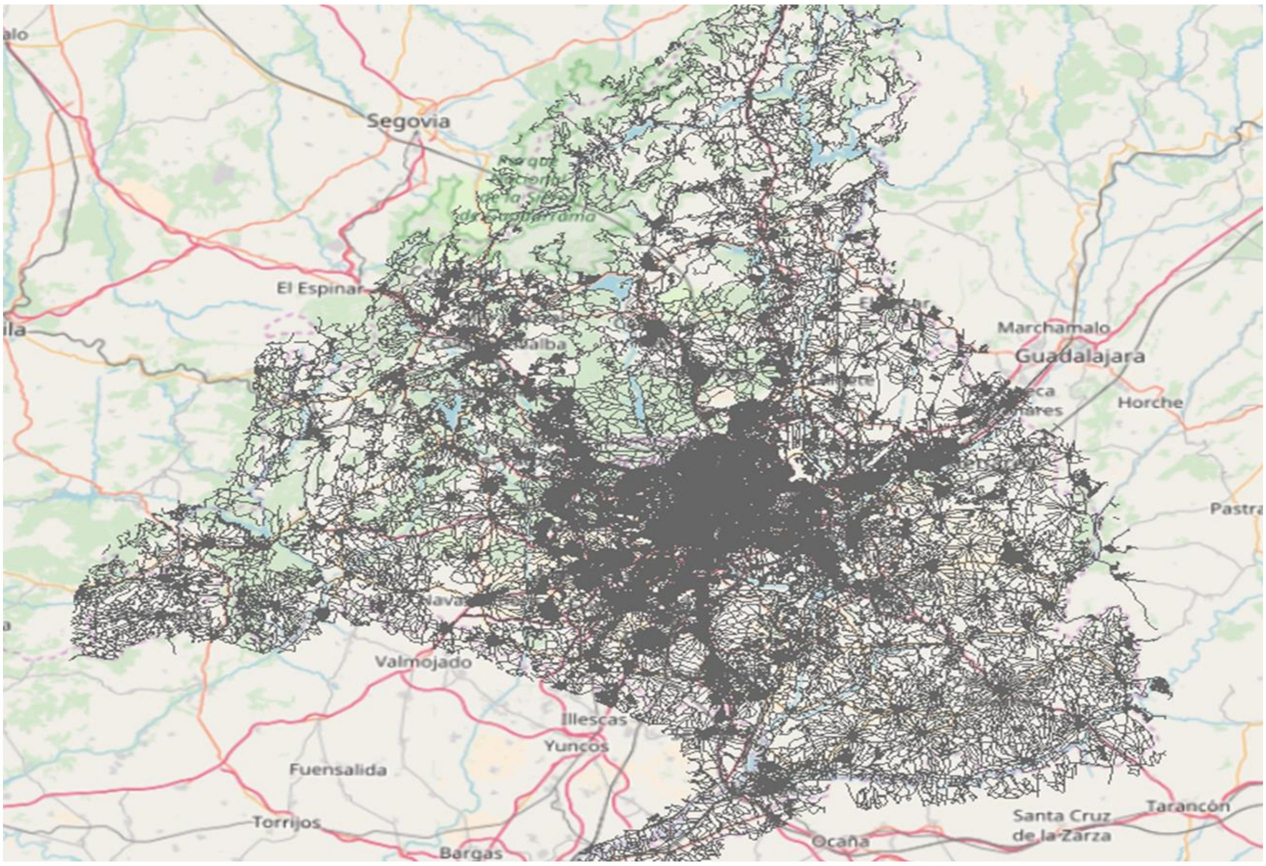

Figure 8 – Madrid private vehicle network in the EMT Madrid model

3.4.2 Transport modelling innovations within MOMENTUM case

The main novelty is to implement **shared mobility supply** in the model. The continuous changes in supply location, based on previous demand, are a challenge for both software providers and mobility planners. Also, the analysis of the demand is quite important to understand citizens' behaviour and the potential impacts of shared mobility within the city and its mobility.

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3.5 Integration of transport models in the urban policy cycle

3.5.1 Current integration mechanisms

EMT's mobility model is a recent development. Therefore, has not traditionally been used for mobility planning of the city. However, in the recent years it has been used for:

- Impact analysis of traffic restrictions of **Madrid Central Area.**
- Definition of the substituting bus service during the **closure of part of the commuter railway** train (Cercanías).
- Definition of the starting and ending point of the new "**Zero Emissions Zero Cost**" bus lines crossing the Madrid Central Area. These new lines are one of the first measures implemented included in the "Madrid 360" strategy.

The main limitation is the recent development of the Model. Also, the Model is not owned by the city but by EMT.

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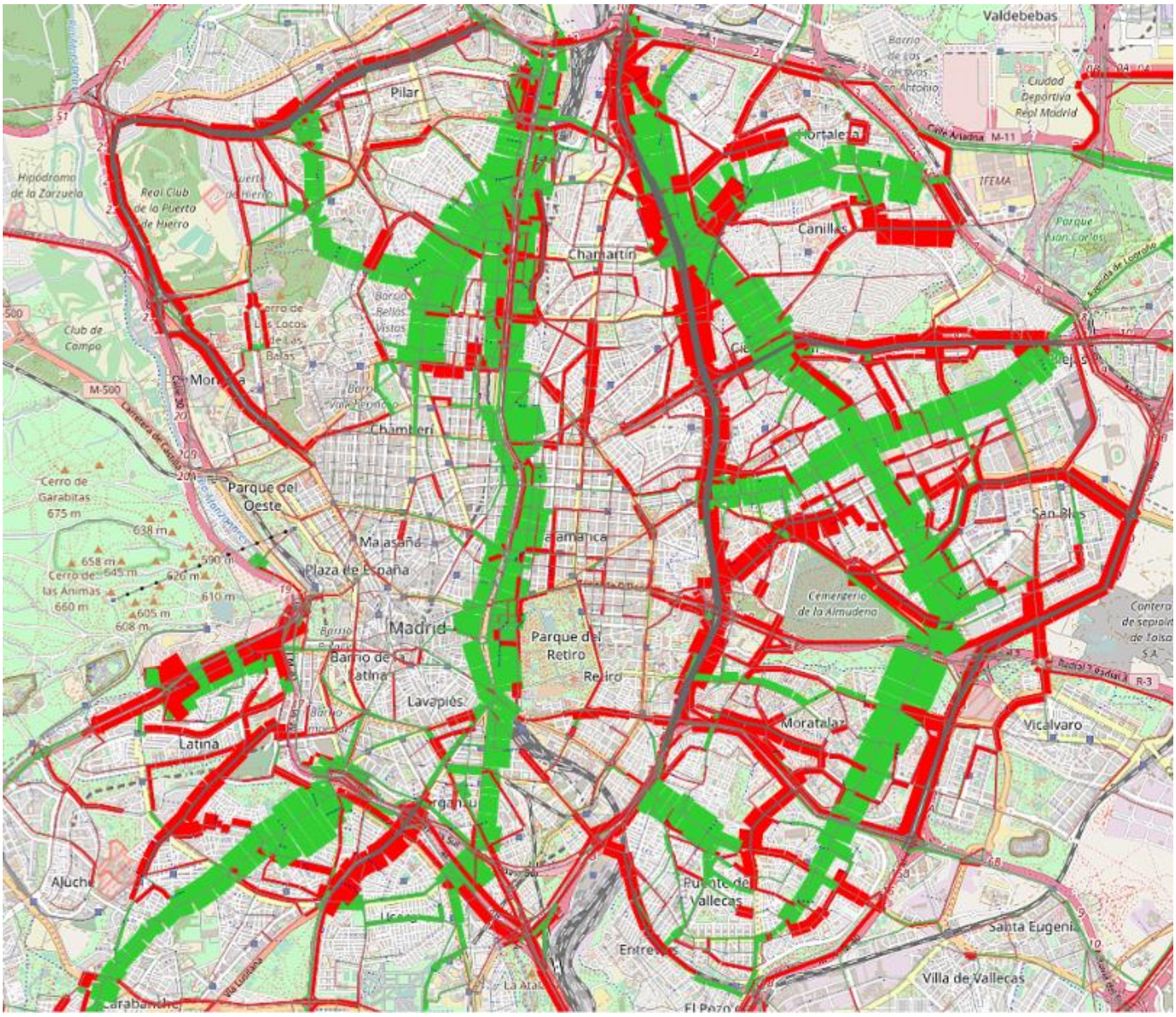

Figure 9 - Simulation of the traffic flows after Air Quality Plan implementation in the EMT model. Source: EMT Madrid

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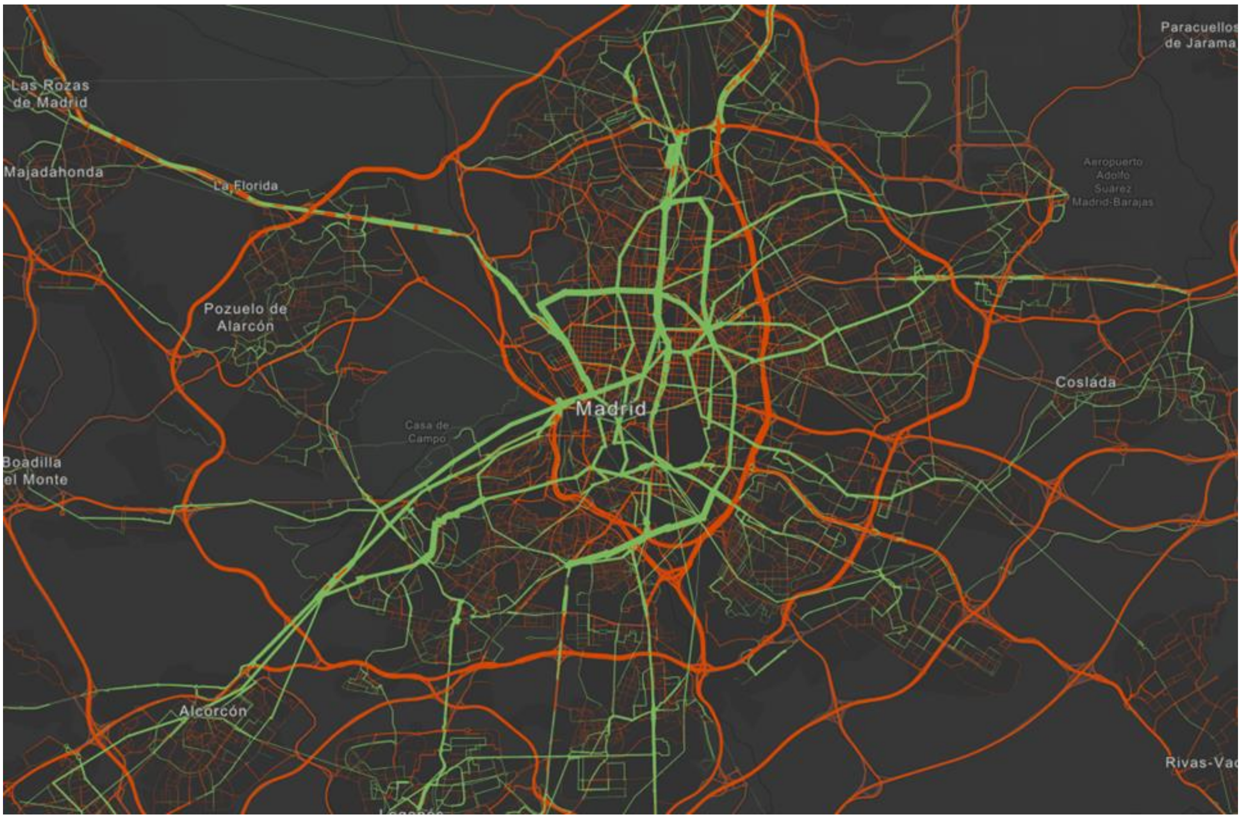

Figure 10 – Public transport (green) and private vehicle transport (red) networks loaded with demand in the EMT Madrid model. Source: EMT Madrid.

3.5.2 Transport models integration initiatives within MOMENTUM case

The inclusion of shared mobility phenomenon in Madrid' transport modelling tools will improve their usefulness, since many of the transport challenges that the city is facing are related to the impacts of these emerging services. The outcomes of the case study will be tailored to the needs of public authorities in this field, e.g. provision of indicators for drafting regulatory strategies, impact assessment on public transport services, etc.

The MOMENTUM local stakeholder group, formed both by public and private key players in the field of mobility in Madrid, will review and evaluate the functionalities offered by the developed tools. In addition, those stakeholders which are involved in modelling tasks in the city will be invited to workshops where the tools will be demonstrated. This will be part of the engagement strategy to be developed for the constitution of the local stakeholder group during WP6.

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4. City of Regensburg

4.1 City characteristics

4.1.1 City overview

Table 10 – City of Regensburg overview

Population	168,426 (first and second residence, 2019, www.statistik.regensburg.de) Est. 33,000 students (2019, own estimation; just first and second residence included in proportions below) 27 % of inhabitants under 25 years old (2019, www.statistik.regensburg.de) 16 % of inhabitants above 65 years old (2019, www.statistik.regensburg.de) 0.2 % of country population (2018)
Area	80.7 sq. km
Density	2,087 people per sq. km
Average annual precipitation days	111.4 days per year (wmo; ref. period 1971-2000; min. of 1 mm per day)
GDP	11,976 million EUR (2015, Bayerisches Landesamt für Statistik) 0.4 % of country GDP (2015, Bayerisches Landesamt für Statistik)
Economic sectors	The City of Regensburg -as the center of Eastern Bavarian conurbation with 2.5 million inhabitants- is more than 2,000 years old and located at the northernmost point of the Danube, about an hour's drive from both Munich and Nuremberg. The historically and culturally significant city is not only a UNESCO World Heritage site and an international tourist destination (Regensburg old town is the largest north of the Alps with nearly 1,500 listed buildings), it has also developed over the last few decades to become one of the major economic centres of Germany and a prosperous center of commerce and industry (since 2000, Regensburg ranges among the top 15 German business locations). Leading international corporations such as BMW, Osram, Infineon, Continental, E.ON, Schneider Electric and Siemens, as well as Krones, Maschinenfabrik Reinhausen and thriving small and medium-sized businesses are based in the city. The main focus is on the sectors Automotive Industry, Electrical Engineering, Energy Supply and Medium Voltage Technology, Mechanical Engineering, Information and Communications Technologies and Biotechnology. Regensburg has a long-standing cluster strategy and runs technology networks and triple-helix clusters in various future areas: Life Sciences, IT-Security, IT-Logistics, Sensor Technologies, Energy / E-Mobility, Healthcare as well as Culture and Creative Industries. Aside from the industrial sector, tourism contributes a lot to Regensburg's economic growth, especially since 2006, when the city gained status as UNESCO World Heritage site. Tourism figures have nearly doubled within the last 15 years and

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	Regensburg has become one of the most-visited German cities from 100,000 to 500,000 residents. Regensburg‘s unemployment rate is below state and federal average, while the employment density is the second highest among German cities. Regensburg’s gross domestic product sums up to 83,000€ per capita. Regensburg is also known for its institutions of higher education. The biggest of those is the University of Regensburg, founded in 1962. The campus is situated in one area, together with the Regensburg University of Applied Sciences. Since 1874 there has been a College of Catholic Music in Regensburg. In addition, there are several research institutions, like the Leibniz-Institute for East and Southeast European Studies (IOS), the Regensburg Centre for Interventional Immunology (RCI), the Fraunhofer Institute for Toxicology and Experimental Medicine (ITEM), as well as the business incubators like BioPark and TechBase. Furthermore, the university medical center is able to provide tertiary care.
Unemployment rate	2.8 % (December 2016, Bayerisches Landesamt für Statistik)
Higher education rate	14% for the Regensburg greater metropolitan area at level ISCED 6, and 22% at level ISCED 5. The reported value for Regensburg municipality is 45%.

4.1.2 Mobility overview

Table 11 - Mobility of Regensburg overview

Public transport network	Regensburg's train station, with an average of 30,000 train passengers boarding per day (2019), connects Regensburg directly with Vienna, Nuremberg, Munich, Frankfurt, Berlin and other cities through long-haul high-speed trains ICE. The international airport Munich can be directly reached by a local train once an hour. There is also a network of local trains which connects the periurban and rural hinterland of Regensburg with the city with a frequency of 30 minutes on working days. Local public transport is operated by SMO (city lines) with an own bus fleet of 131 vehicles (5 of which are full electric; Dec. 2019) and by GfN (regional lines) with instructed bus companies. The city lines cover 5.5 million vehicle kilometres per year (2019, RVV). To grant an integrated tariff for both the city and the surrounding communities, as well as for railways and buses, there is a transport organisation (Regensburger Verkehrsverbund). In the past years, the demand for public transport has grown, but also the demand of other modes of transport. Individual transport has increased, which lead to congestion mostly at the edge but also inside the city. To attract more passengers towards public transport, the city administration has the intent to implement a light rail system. The administrative process is already running, but a reliable date of installation cannot be set at the moment.
Active modes infrastructure	The city's total street network is about 414 km. Accompanying bike paths are laid out on the main streets. In the old town, with an area of 1.1 sq.km, an area of approx. 0.2 sq.km is designated as a pedestrian zone. This pedestrian zone is open to cyclists. Around the old town is a green belt exclusive for pedestrians and cyclists with a

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	length of approx. 3 km. As a test, Regensburg opened 2 cycling streets in 2019, with a length of 1 km. There are approx. 1,200 bicycle parking spaces with brackets in the old town. However, first and foremost, Regensburg is a city of short distances. Cycling has a great potential.
Car ownership	467 vehicles per 1,000 inhabitants (2016, www.statistik.regensburg.de) 23% households have no car; 58% households have one car; 19% households have two or more cars (SrV2018)
Total trips per person	On average 3.5 trips per person per day living in Regensburg (SrV2018) On average 3.2 trips per person per day living in a city in Germany (city size between 100 - 500 K.; MiD2017)
Average trip distance	On average 5.6 km per trip by person living in Regensburg (SrV2018) On average 11.0 km per trip by person living in a city in Germany (city size between 100 - 500 K.; MiD2017)
Modal split	There are several modal split estimations (on foot / bike / public transport / personal vehicle) from two different household surveys. All trips by persons living in Regensburg: 24%/24%/11%/41% (SrV2018) All trips by persons living in a city in Germany: 24%/14%/12%/50% (city size between 100,000 and 500,000 inhabitants; MiD2017)
Shared mobility options	Regensburg has been very active in exploring various novel mobility services and concepts. One of the larger ones includes **bikesharing**, with about 600 shared bicycles to start operations in 2021, about half of which will be pedelecs. The bikesharing system is partly station-based and partly free floating, and will be operated by SMO in collaboration with a private company. The current **carsharing** system (das Stadtwerk.Earl) is planned to expand from 5 to 20 vehicles. The fully electric fleet is station-based, and is operated by SMO. The carsharing system is active since 2016. 1,920 people are currently registered (status as of December 31st 2019), and 139,400 vehicle kilometres were driven in 2019. A smart parking application (ParkPocket) has been launched, in collaboration with Continental Corporation at the parking area of the local soccer stadium, Arena Regensburg, to offer cashless payment for the customers. Since the start of the pilot project in December 2018, 424 parking tickets have been sold. The aim is to increase the number of tickets sold via the smart parking application, and to establish it as a common payment method. **Scooter-sharing** will be run by a private company with a capacity of 50 scooters from February 2020. An expansion to 150 scooters is also planned.
CAVs initiatives	An autonomous people mover (shuttle with a capacity of 6 people) along a predefined area in the city will run from November 2020 for a two-year test period.
Urban air mobility initiatives	-

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Mobility planning and governance	The **city council** is responsible for all local roads and, of course, developing and implementing local policies. The last official traffic development plan from 1997 is out of date. At the moment, transport policy decisions are based on the master plan for Energy and Climate, which identifies key long-term goals, indicators and actions. A wide range regional traffic investigation is currently being launched with a multimodal approach. The **state building authority** (belongs to the state Bavaria) is responsible for primary roads. The **highway authority** (belonging to the Federal Republic of Germany from 2021) is responsible for highways. **Stadtwerk Regensburg Mobilität (SMO)** is responsible for the public transport planning in the city of Regensburg. The RVV is the operator in the city. The GfN operates the regional lines through private companies. **Deutsche Bahn** is responsible for the public transport planning concerning the railroads. Evidently there are several key players that need to be involved in general policy making. These key players, called "coordination round transport", have been meeting annually for past 18 years to coordinate infrastructure projects. In 2005, a joint traffic investigation in the conurbation of Regensburg was utilised to generate improvements in the mIV through road construction measures. With the traffic investigation now beginning, multimodal solutions are to be developed.
Mobility culture	In Regensburg, the transport policy of the past decades was primarily geared towards private transport and major road projects are still going on, such as the 6-lane expansion of the A3 motorway, the renovation and expansion of the Pfaffenstein tunnel on the A93 motorway, and the construction of a new connecting link between the BAB A93 and the Regensburg Easter through the construction of the Bridge "Sallerner Regenbrücke" in and around Regensburg. As soon as these main arteries become blocked, traffic pours into the urban area of Regensburg and leads to congestion on all of the city's main thoroughfares. Regensburg's strong economic development attracts many commuters (approx. 80,000 per day) from the surrounding area. Due to increasing congestion and short trip distances, the willingness to bike is increasing among the population. Regensburg also has a comparatively young population, which is generally more open to new forms of mobility. In addition, many innovative companies in the field of information technology and mobility are located in Regensburg. Overall, there is criticism among the urban population for public transport, which is often not attractive enough compared to cars or bicycles, because of the long travel times. The medium-term realization of a new central bus station in the immediate vicinity of the main train station is intended to increase the attractiveness of public transport. Many people wish for a light rail system (introduction of a higher-quality public transport system), but it is still a long way off due to the long planning phase. Initiatives by the city administration to calm traffic in the old town and to change the pricing of parking lots close to the old town are often critically assessed by retailers in the old town, which compete with shopping malls in the periphery. In the city, e-mobility is actively supported by a funding program for e-cars and e-bikes and is very well received by the city population.

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Mobility policy priorities	The mobility policy priorities can be identified by reviewing the past transport planning initiatives and implementation projects: • Introduction of an **environmental zone** in 2015. • Construction of **park and ride** facilities in 2015 (Regensburg Arena). • **Network additions** in the road network 2006-2014. • Introduction of a **direct rail connection to Munich Airport** (ÜFEX), as well as reduction of the headway in the Regensburg rail network. • **Headway reduction (densification) in the core network of urban public transport**, introduction of express bus lines to important destinations in the city area, introduction and gradual expansion of the night bus network, introduction of new bus lines in individual city areas and to large companies in the city area (including the BMW plant). The official launch of the electric Altstadtbus fleet for a liveable inner city was completed in 2017. The upcoming initiatives focus on public transport improvements and less on road capacity. The execution of a wide range regional traffic investigation with a multimodal approach is part of the policy priorities. With regard to particular projects, the following can be mentioned: • **Traffic reduction in the old town** • Development of a **new parking pricing system** • Construction of a **new central bus station** • Development of a new **light rail system** • Extension of existing and implementation of new **shared mobility systems**: carsharing, bikesharing, e-scooter sharing • Implementation of an **autonomous people mover**

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4.2 Scope of the case study

4.2.1 Questions to be addressed

The main objective of the Regensburg case study is to have a reliable model for deriving scenario outputs and guiding evidence-driven policy input by **integrating the new mobility services into the existing model**. The city has been very active in exploring various novel mobility services and concepts. One of the larger ones includes **bikesharing**, with about 600 shared bicycles to start operations in 2021, about half of which will be pedelecs. The bikesharing will be partly station-based/free floating. The current **carsharing system** is planned to expand, based on initial feedback, and an **autonomous people mover** (shuttle with a capacity of 6 people) along a business park outside of the city centre is planned. Also, a **smart parking application** has been implemented, in collaboration with Continental Corporation at the parking area of the local soccer stadium “Arena Regensburg”. While the level of air pollution is not as high as in other cities, air quality is an increasing concern and is considered one of the main priorities of the city, together with the preservation and regeneration of the city centre, recognised as UNESCO World Heritage.

Within this context, the case study will address these questions:

- Vehicle automation opens the room to innovative transport supply schemes. **To what extent can the autonomous people mover complement conventional public transport services?**
- Shared mobility services claim to reduce the need for owning a car. **To what extent the shared mobility services implemented in the city have an impact on car ownership?**
- Air pollution is at the top of policy priorities affecting urban mobility. **What is the impact of the new mobility options on air quality?**

4.2.1.1 Time horizons of the analyses

- The bike-sharing and the car sharing service are expected to be expanded in a short term (1-3 years), with their impacts expected on a midterm horizon (4-7 years).
- Autonomous people mover will be operated from October 2020 for a test period of two years. After that time, the city together with SMO will decide, if the project continues and also where the new operation area will be.

4.2.1.2 Policies to be tested

Apart from the implementation and effects of bikesharing, carsharing and the autonomous people mover, the case study will address the **extension of exclusive bus lanes**, taking into account the interaction with these new mobility services.

4.2.2 KPIs

- Car ownership (number of vehicles per 1,000 inhabitants)
- Modal share
- CO_2 emissions
- Travel times (link level travel times during peak and non-peak hour)
- Usage rate (trips per vehicle per day) for the bike-sharing and car-sharing systems

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4.3 Data sources

4.3.1 Usual input data sources in transport planning

Table 12 - Data sources usually employed as input for transport modelling and analyses in Regensburg

Data source	Description	Provider	Role
Public Transport Schedules and Lines	Public Transport Schedules and Lines	Stadtwerk Regensburg Mobilität GmbH (SMO)	Basic information for traffic model
Transport Network	Transport Network	NAVTEQ (currently HERE)	Basic information for traffic model
Mobility Survey	Mobility survey carried out in 2011	City of Regensburg	Source used to illustrate need and potential for behavioural change;
Traffic Data	Traffic counts	City of Regensburg	Collected until 2011 and is used for calibration
Other Public Transport Data	Passenger counting data for every bus line inside city of Regensburg	Stadtwerk Regensburg Mobilität GmbH (SMO)	Calibrating modal share

4.3.2 Data sources explored within MOMENTUM case

Table 13 - Data sources to be explored within MOMENTUM project in Regensburg

Data source	Description	Provider	Role
Other Public Transport Data	Passenger counting data for every bus line inside city of Regensburg for the whole year of 2019	Stadtwerk Regensburg Mobilität GmbH (SMO)	Calibrating modal share
Public Transport Schedules and Lines	Delay and arrivals ahead of schedule sorted by line	Stadtwerk Regensburg Mobilität GmbH (SMO)	Calibrating PT schedules

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Data source	Description	Provider	Role
Cycling Data	Manual bicycle counting and frequency survey	city of Regensburg	Calibrating traffic flows, modal share
Pedestrian Data	Manual pedestrian counting and frequency survey	city of Regensburg	Calibrating traffic flows, modal share
Car/Moto-Sharing Data Demand	Car sharing Data Demand	REWAG Regensburger Energie- und Wasserversorgung AG & Co KG	Calibrating modal share
Traffic Data	Data from traffic sensors	State of Bavaria	Calibrating traffic flows
Traffic Data	Floating Car Data for retrieving travel times information	Floating Car Data providers (e.g. INRIX)	Traffic congestion calibration
Weather Data	Weather Data	Darksky	Context variable

4.4 Transport models

4.4.1 Current transport modelling tools

The city currently uses a **conventional 4-step model**, implemented in PTV VISUM, which follows an **aggregated static** modelling approach. The model was set up in 2011, and was updated once in 2014 (with new network data). The demand model uses a tour-based approach (VISEM). Modes simulated within the model include private cars, trucks, Public Transport (PT), pedestrians and bicyclists. RVV bus system, regional bus system, regional rail system, and walking for first and last mile of PT are included under PT mode. The different modes are distinguished in the mode choice model. Commercial trips are defined externally and attributes for the same are user-defined. For public transport, the network loading component is purely timetable based. For pedestrians and cyclists, there is no network loading component. Data for the road network is from NAVTEQ (currently known as HERE).

The production/attraction and the mode choice components are calibrated based on the mobility survey carried out in 2011, available census data and other socio-demographic data.

Following are the main limitations of the model:

- Cycle traffic is not captured by the model.
- Emerging mobility services such as bike-sharing and car-sharing are not captured by the model.
- Evaluation of the impact on car ownership level is not possible.
- Impact of policies such as exclusive bus lanes cannot be modelled.

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4.4.2 Transport modelling innovations within MOMENTUM case

The objective of this case study is to improve the capability of the existing model to simulate the bikesharing and the carsharing system in an efficient way, so as to answer the policy questions aforementioned.

Reduction of car ownership and use is a major objective being aimed in the city council. Hence, the effect on car ownership is seen as a crucial element. Therefore, the update to the existing model should consider the relationship between the availability of shared mobility services and car ownership.

The resulting improved model from the project should be able to model policies like implementation of exclusive bus lanes and time restrictions for truck traffic.

4.5 Integration of transport models in the urban policy cycle

4.5.1 Current integration mechanisms

The traffic model is used as a basis for traffic forecasts and for various investigations, such as:

- Efficiency calculation of the city light rail system.
- Evaluation of the traffic generated by the development of new city areas.
- Traffic function plan for a new central bus station.

On the one hand, the forecast data are used to carry out noise calculations and, on the other hand, to check the traffic development in new city areas.

In addition, the model is used for short-term and strategic considerations, e.g. to estimate the impact of road closures.

4.5.2 Transport models integration initiatives within MOMENTUM case

The improved model will be used as a basis for making planning and policy decisions related to **expansion of carsharing and bikesharing systems**. The improved model will also be utilised **to test the impacts of autonomous people mover**, which will be further utilised to make decisions related to implementation of such a system in future. Discussions with policy makers will be held to clarify the necessity for regular model updates and the advantages of such updates, in order to make use of efficient models in the future for policy making.

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5. City of Thessaloniki

5.1 City characteristics

5.1.1 City overview

Table 14 – City of Thessaloniki overview

Population	325,182 (municipality, 2011) - 1,012,297 (metropolitan area, 2011) 25.0% of inhabitants under 25 years old (municipality, 2011, ELSTAT) 20.7% of inhabitants above 65 years old (municipality, 2011, ELSTAT) 3% of country population (municipality, 2011) - 9.4% of country population (metropolitan area, 2011)
Area	19.307 sq. km (municipality) 1,285.61 sq. km (metropolitan area)
Density	16,842 people per sq. km (municipality) 787 people per sq. km (metropolitan area)
Average annual precipitation days	On average there are 96 days per year with precipitation > 0.1 mm. More specific in 2018 we had: precipitation > 0,2 mm 119 days (2018, source: municipality of Thessaloniki) precipitation > 2,0 mm 54 days (2018, source: municipality of Thessaloniki) precipitation > 20 mm 3 days (2018, source: municipality of Thessaloniki)
GDP	About 4,180 million EUR (municipality, 2016, estimation based on the GDP per capita of the Central Macedonia of 2016 (ELSTAT) and the estimated municipality's population for the same year) - 21,155 million EUR (region of Central Macedonia, 2016, ELSTAT) 2.7% of country GDP (municipality, 2016) - 13.7% of country GDP (region of Central Macedonia, 2016, ELSTAT)
Economic sectors	In 2018, the region of Central Macedonia employed 16.8% of the country's workforce: 68.8% in the tertiary sector, 16.5% in the secondary sector and 14.6% in the primary sector (2019, Eurostat). Also, regarding each sector's % of GDP: • **Primary sector**: 2.4 % of the regional GDP (milk, wheat, rice, cotton) • **Secondary sector**: 24.9 % of the regional GDP (food and drink, construction, furniture) • **Tertiary sector**: 72.7 % of the regional GDP (trade, tourism) "The most important services sectors in the region are financial services, transport and communications, recreational, tourism and transport services. The manufacturing sector is dominated by medium to low technology intensive sectors,

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	such as the food industry, textiles and clothing, non-metallic mineral products and furniture where the majority of firms are SMEs. Larger companies are found in industries such as metal production, chemicals and plastics. The main exporting sectors are those of textiles, food and drink, chemicals and plastics." [3]
Unemployment rate	20.4% (2018, ELSTAT)
Higher education rate	43.7% (2018, Eurostat). This percentage corresponds to the share of people aged 30-34 years that have completed a tertiary educational attainment.

5.1.2 Mobility overview

Table 15 - Mobility of Thessaloniki overview

Public transport network	The service area of the public transport covers most of the Regional Unit of Thessaloniki, combining inner city and some suburban bus connections. Currently, 79 inner city bus lines operate, which ran 28.7M service vehicle kms in 2018, instead of the scheduled 38.8M service vehicle kms (source: TheTA strategic plan). The number of vehicles is about 622 and the number of stops in the whole area is around 3,500 (OASTH, 2019). However, it should be noted that the aged fleet and the inability to invest during the transition from the private to the nationalized operator resulted in a significant reduction in public transport supply. For those living in the outskirts there is limited possibility to reach the city centre without using the private car, especially at night, because public transportation does not operate after midnight. Six suburban bus line also operate within the Regional Unit of Thessaloniki. The existing public transport system based on buses will be open to new companies, so there will be more competition, which is expected to lead to better and cheaper services. Furthermore, metro network is estimated to be operable by the beginning of 2023.
Active modes infrastructure	Although the climate and the landscape of the city favours the bicycle use, cycling levels are very low in Thessaloniki [4] and there is no coherent cycling network in the city. The bicycle lanes network currently operating in Thessaloniki has a total length of 11.7 km and does not provide sufficient accessibility to bicycle users. The bicycle is currently used for leisure activities mainly across the city's waterfront where there is adequate cycling infrastructure. However, it is estimated that the implementation of the Sustainable Urban Mobility Plan (SUMP) conducted by the local authority will change the current unsafe and uncomfortable environment for cycling through appropriate interventions [5].
Car ownership	475 vehicles per 1,000 inhabitants (municipality, 2013, Observatory of Egnatia Odos)
Total trips per person	Average number of trips per person: 2.6 (2017, Thessaloniki's SUMP)
Average trip distance	3.5 km (municipality, 2017, SUMP Thessaloniki) and 11.0 km (metropolitan area, 2017, SUMP Thessaloniki).
Modal split	Within the municipality (2017, Thessaloniki's SUMP): public transport 40% - private cars 26% - walking & cycling 21% - motorbikes and taxis 13%

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	Within the metropolitan area (2017, Thessaloniki's SUMP): private cars 41% - public transport 34% - motorbikes 11% - taxis 3% - walking 9% - cycling 2%
Shared mobility options	It is possible to find three shared mobility services in Thessaloniki: • A **station-based bikesharing**, named ThessBike, operates since September 2013. From its foundation until October 2018, 16,000 members have been registered and 92,000 rentals have been made. There are currently 200 bicycles and 8 stations, mainly located in the city centre. More specifically, the demand is distributed in a similar manner per month for all years of operation of the system (2013-2018) and two peaks appear, one in May (more than 3,000 rentals) and the other in September (more than 2,500 rentals), due to the favourable weather conditions in the city. The distribution of hourly demand is differentiated according to the season; during summer demand is low during the day but peaks sharply appear in the afternoon, contrary to the winter season which reveals the opposite pattern. Spring and autumn hourly demand distributions follow similar motives. • **E-scooter micromobility** services, operated by Lime and Hive, launched at the end of 2018 and 2019 respectively. • A **pilot taxi-sharing service** is implemented within the framework of the Galileo 4 Mobility project (http://www.galileo4mobility.eu/). The service aims at limiting the traffic congestion in the city centre by reducing the commuting trips from 2 zones located at the eastern part of the city (Thessaloniki and Thermi). A fleet of 150 taxis of the Taxi Way company collect users (currently 40 registered users) of the Thessaloniki regions and transport them to the city centre and back to their home aggregating as much as possible the trip origins and destinations aiming at concentrating trips in a few vehicles.
CAVs initiatives	Services for connected vehicles are currently being implemented in the city of Thessaloniki within the framework of the COMPASS4D and the C-MobILE projects. More specifically, the Cooperative Intelligent Transportation Systems (C-ITS) services which will be demonstrated in large-scale and to large numbers of end-users are: Road Works Warning, Road Hazard Warning, Flexible Infrastructure, GLOSA, In-Vehicle Signage, Mode and Trip Time Advice, and Probe Vehicle Data. Other services will be implemented as well either in limited scale, i.e. Warning System for Pedestrians, or as proof of concept, i.e. Emergency Vehicle Warning, Signal Violation Warning, Green Priority, Cooperative Traffic Light for Pedestrian. All the above-mentioned services will be accessible to end-users/drivers through one common application which will be providing information about road works/hazards, traffic light status, travel times, road signs, etc. These solutions could be correlated to automated driving considering that advice provided through the C-ITS services could be embedded in the vehicle systems. Hence vehicle perception, decision making, and operation will be performed by the vehicle electronics and machinery will take into account the advice provided through C-ITS services.
Urban air mobility initiatives	-

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Mobility planning and governance	Urban public transport in Thessaloniki is governed by Law 4482/2017, which transformed the existing, at that time, public transport authority (ThePTA) into a **Transport Authority (TheTA)** and nationalized the incumbent private urban transport operator. Moreover, the Law stipulates that until the establishment of new urban public transport operator (ASYTH), services will continue to be provided by the incumbent (OASTH). Intercity and regional public transport is provided by regional transport operators under Law 2963/2001 and for the Regional Unit of Thessaloniki, **KTEL Thessaloniki** constitutes such an operator that, except for intercity connections, it also provides public transport services in suburban (6 lines) in areas beyond the service area of OASTH or provides public transport services on behalf of OASTH, under contract. Finally, a limited number of Municipalities within the Regional Unit of Thessaloniki (Municipalities of Ampelokipon-Menemenis, Volvis, Thermis and Kordeliou-Evosmou) provide free intra-municipal public transport services, primarily serving municipal areas that are not covered by the OASTH network. The municipality of Thessaloniki is aiming to improve the quality of citizens' life and transform the city into a more sustainable place to live, has developed the **Sustainable Urban Mobility Plan (SUMP)** in collaboration with the Hellenic Institute of Transport (HIT). The 3rd public consultation council of the SUMP was held on July 2019 and after the integration of participant's suggestions, the final version of the SUMP has been delivered and is currently under the approval process by the municipal council of Thessaloniki. The main responsible authority for the implementation of the SUMP is the municipality of Thessaloniki. The SUMP is developed under two future time scenarios: 2023 and 2028. **CERTH/HIT** in cooperation with its ecosystem's stakeholders provides transport research and supports policy- and decision-making in land, maritime, air and intermodal transport operations, organisation, planning, standardisation, economic analysis, management, mode technology and impact thereof.
Mobility culture	Mobility is perceived as an issue of high importance by the citizens. The most critical issues that are mentioned in various surveys in Thessaloniki are **safety**, **lack of parking spaces**, **congestion** and the **low level of service of public transport services**. Overall, the citizens of Thessaloniki are highly dependent on their private vehicles for satisfying their mobility needs. The city authorities have been allowing this behaviour during the last years by relaxing the parking constraints in the city, especially in the areas surrounding the city center, but also in the city center itself. At the same time, public transport supply was poor so there was no alternative to the use of private cars. Taxis has been a largely-used alternative, event by students due to the low fares applied and the high availability of taxis. This situation was mitigated during the worst years of the economic crises, but still the use of taxis as a daily mode of transport remains as a common habit for certain groups. Motorcycles are also present in the city: weather is nice most of the year so they can be driven most of the time. With regards to active transport modes and micromobility there have been a few boosting attempts during the last years, which are addressed to a concrete sector of the society willing to use them, usually climate-sensitive citizens, while the

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	other users have a negative view on these, by not respecting bike lanes (they use to park there) or cyclist themselves. Thessaloniki citizens are dissatisfied with the operation of the public transport vehicles. The limited current fleet is not able to respond to the volume of travellers who choose this mode for their daily trips. This leads to a non-regularity of the timetable and to over-congested vehicles. The strikes of the bus drivers in 2017 deteriorated the situation and led to a carpooling initiative by the citizens named ThessCarpooling. The carpooling scheme was available through a Facebook group and a mobile application. However, the initiative was not sustainable due to the small number of the registered users. In 2011, another citizen-led initiative was also started, in which an app for keeping parking spaces (Parking Defenders) was developed to share information about the availability of parking spaces. On July 2013 the application was renamed to “Park Around” and the user interface was updated. On May 2019 a **pilot ride/taxi-sharing service** was implemented within the framework of the Galileo 4 Mobility project. Citizens were a bit reluctant at the beginning stating that they are not so familiar with the coexistence with strangers. After nine months of operation, more than 90% of the current users are satisfied or very satisfied with the reliability of the taxi-sharing service and encourage their familiars to participate playing the role of the service’s “ambassadors”. The time saving in their daily trips is chosen by the majority of the users as the main reason for participating in a ride-sharing scheme. On the other hand, there are also often negative reactions to mobility-related suggested changes. The study of the extension of the bicycle lanes network to the western part of the city provokes a negative reaction within a small share of the citizens who complaint for the loss of parking spaces due to the creation of the suggested bicycle network.
Mobility policy priorities	Main upcoming initiatives: • **Operation of metro network**: metro network is estimated to be operable by the beginning of 2023. Furthermore, the project “Extension of Metro line to Kalamaria” executed under Priority Axis 8 “Clean Urban Transport” is expected to provide a safe, quick and clean connection between the city center and the western urban areas of Thessaloniki. • **Pedestrianization of specific parts of central roads:** this initiative aims to support the entrepreneurship and cultural heritage of the city creating a resilient environment. Sustainable transport modes such as electric cars, bikes and micromobility vehicles will be allowed in these areas. • **Extension of the bicycle network:** the study of the extension of the bicycle lanes network was recently completed. It suggests the creation of a cycling infrastructure network both at the western and the eastern part of the city and its connection with the main central network. • **Restructuring of Thessaloniki's public transport network:** in the following years, a reconstruction of the public transport network will be executed in order to increase the accessibility of the users. • **SUMP’S for all the municipalities of Thessaloniki’s Regional Unit:** in the coming years, all the municipalities of the metropolitan area of Thessaloniki

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will get their own SUMPs since they have already received funding from the Ministry of Environment.

With regard to research initiatives, Thessaloniki has been appointed as one of the transport pilots in the Big Data Europe project (BDE - https://www.big-data-europe.eu/), having access to the project's infrastructure and technical and advisory support in the field of the multi Domain Big Data in Europe. The city has also been selected by the IMOVE project (https://www.imove-project.eu/) as Innovation Pathfinder to be benefited from transferability exercises in which IMOVE experts will assess the current status of transportation system and provide tailored suggestions on how to refine and improve aspects of the MaaS schemes related to users and stakeholders' engagement, organisational and business models, ICT solutions for MaaS operation and enhancement and data sharing issues/solutions in MaaS applications. Finally, since 2019, Thessaloniki Smart Mobility Living Lab is an adherent member of the European Network of Living Labs with strong collaborations between Living Lab experts and practitioners worldwide towards the enhancement of its activities through new tools and services.

5.2 Scope of the case study

5.2.1 Questions to be addressed

The overall objective of Thessaloniki case study is to **improve the planning and decision-making process** for the introduction of resilient sustainable mobility schemes, with main emphasis in **adoption of DRT, ridesharing and vehicle sharing** (micromobility, bike and electric car) mobility solutions towards MaaS in the agglomeration. This will serve also to develop techniques which can **facilitate proofs of concept** of new mobility schemes and the to improve and extend the **use of innovative data sources** (Floating Car Data, point-to-point detections, social media, etc.) in the transport modelling process.

The specific questions to be addressed are the following:

- **How DRT should be implemented to contribute to sustainable mobility?** DRT systems are expected to play a role in the surrounding of the agglomeration, where the population density is low. It can be based on flexible bus lanes or on a ride-sharing service where taxis will feed the perimetral bus stations, so this choice will be explored under this question. The application of MOMENTUM tools to the case study will provide insights on the number of vehicles needed, the most appropriate service characteristics (frequency, capacity, etc.) and the pricing strategies for such a service. In addition, the techniques for an efficient clustering of users in the case of ridesharing-based DRT will be explored.
- **What is the role of ridesharing in the transport system of the city?** Ridesharing has been already implemented in the framework of the GALILEO4MOBILITY project in 2019, providing taxi-sharing services to people living in suburban and peri-urban areas (1 of each) towards the city center and back home. The tools developed during MOMENTUM will evaluate this service and possible extensions in the following terms: How should the ride-sharing service be designed? How many people per vehicle? What areas should be served? What periods of the day? For what kind of trip purposes?
- **What are the impacts of bikesharing and micromobility in transport planning?** Vehicle-sharing schemes will perform better between the city center and the suburban and peri-urban areas for electric cars, while for bike sharing and micromobility it may work better if limited to the city center and the suburban areas only. The focus will be on its relation to cycling infrastructure, by exploring the potential contributory factors for the bike lanes network planning. In addition, the evaluation of current and planned bikesharing

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schemes will be done through MOMENTUM tools: fleet size, bikesharing model (dock or dockless), distribution and rebalancing operations… Some of the parameters and modelling techniques applicable to bikesharing and micromobility are also applicable to **electric carsharing**.

The research conducted for exploring the above questions paves the way for the implementation of MaaS schemes in Thessaloniki. Bundling all the above services together, and engaging the public transport authority responsible for the buses and the metro, a door2door MaaS service could be offered in Thessaloniki.

5.2.1.1 Time horizons of the analyses

All of the three services that will be examined and adopted in the city of Thessaloniki within the case study of MOMENTUM project are emerging mobility trends, which can be perceived as different reflections of the shared economy concept in urban mobility. Although this implies uncertainties in their evolution, it is possible to state that each of the three services has a different time horizon (short, medium and long term):

- DRT service: both the implementation of the DRT service and their effects are expected during the next 3 years (**mid-term horizon**).
- Ride sharing service: the implementation of the ride sharing service is expected on **short-term horizon** (1-2 years) since a pilot ride/taxi-sharing service is already implemented within the framework of the Galileo 4 Mobility project. Its effects are focused on a decrease in private car use and therefore in congestion. Since such effects requires time to become visible, they are expected on a **mid-term horizon** (5-10 years).
- Vehicle sharing schemes can be divided into two groups with different time horizons:
    - Bike and micromobility sharing schemes are already implemented in Thessaloniki and thus their effects are expected to become visible on a **mid-term horizon** (5-10 years).
    - On the other hand, both the implementation and the effects of the electric carsharing are expected on a **long-term horizon** (10-15 years).

5.2.1.2 Policies to be tested

- Flexible bus services in the peri-urban areas.
- Ride-sharing service for feeding public transport and/or for door2door trips between the suburban areas and the city center.
- Provision of cycling infrastructure.
- Provision of vehicle-sharing services (electric cars, bicycles and micromobility vehicles)
    - Distribution of vehicles within the city.
    - Rebalancing of vehicles from destination points to points of origin.
- Regulated parking spaces and charging points for the electric car sharing system.

5.2.2 KPIs

The relevant indicators to be measured, both for the analysis of the above questions and for the specific policies are:

- Estimated number of users of:
    - DRT services
    - Ride-sharing services

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  - electric car sharing service
  - bicycle sharing service
  - micromobility services
- Total vehicle, passenger and seat kilometers, fuel consumption and emissions.
- Congestion levels, public transport level of service (waiting time, vehicle occupancy…), commuting time, use of active mobility means.
- Accessibility, network coverage, reliability.

5.3 Data sources

5.3.1 Usual input data sources in transport planning

In Thessaloniki, there is a local ecosystem where private and public stakeholders cooperate for gathering the needed data for transport-related analyses. This has been established during the execution of several projects by its members. A mutual characteristic shared among the members is common understanding cultivated towards innovation in the transport sector. CERTH-HIT and the Municipality of Thessaloniki lie in the core of this environment. Both entities have developed and maintain hardware and software infrastructure to collect transport- and mobility-related datasets for the city of Thessaloniki. Those structured and unstructured data are generated by using both traditional and modern methods and are typically recorded by sensors and devices at high frequencies with high spatial density. This large collection of heterogeneous raw data feed pipelines and algorithms which maintain historical databases and store the datasets in different granularity levels. Further, in the context of transport modelling, CERTH-HIT has leveraged additional datasets provided by other local ecosystem members, for example the taxi association TaxiWay, as described in Table 17. This infrastructure and ecosystem will be utilized during the implementation of the MOMENTUM project.

Table 16 – Data sources usually employed as input for transport modelling and analyses in Thessaloniki

Data source	Description	Provider	Role
Transport Network	Since 2008, CERTH-HIT owns and maintains digitized network files for Greece and other parts of the world. Specifically, for the city of Thessaloniki, the files are available with a high level of detail. The digitized files contain information about regions and districts, road network, bus and bicycle lanes as well as public transport infrastructure. The digitized network datasets consist of fundamental information on shape geometries (coordinates and segment lengths) and functional characteristics (number of lanes, capacity, free-flow speed, traffic lights programs ...). CERTH-HIT also uses additional open digitized network datasets (OpenStreetMap).	CERTH-HIT	Supply side of the models

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Data source	Description	Provider	Role
Land Use Data	Additional data related to households and land uses is available. Moreover, the identification and categorization of significant city or region attractions is also available.	CERTH-HIT & Municipality of Thessaloniki	Validation of the parameters of trip generation model (number of employees - attraction)
Mobility Surveys	Various mobility surveys have been executed during the last years by CERTH-HIT. The last one is on-going and Origin-Destination matrices have been already estimated from it (total and per mode).	CERTH-HIT	Development of trip generation model and mode choice model (stated-preference surveys) and derivation of hourly demand from road side surveys (RSS).
Travel Time Data	Travel time data is available for 218 routes and all road segments in the city of Thessaloniki. CERTH-HIT Portal has developed methodologies and set up the necessary hardware and software modules to automatically calculate the observed travel times between major intersections in the city of Thessaloniki, Greece. At the moment two methodologies are used: (i) data from Bluetooth sensors and (ii) FCD from the taxi fleet. Furthermore, the output of both methodologies is combined in an effort to increase the overall system's output accuracy and credibility.	CERTH-HIT & Taxiway	Calibration of the models
Traffic Data	CERTH-HIT has been granted real time access to traffic data generated by conventional traffic counters installed and operated by the "Region of Central Macedonia" public authority. Those counters are typical electronic devices (radars and cameras) able to identify a vehicle's type (car, motorcycle, truck etc.), as well as its moving speed. The devices transmit raw data to the Traffic Management Center of the "Region of Central Macedonia" where the estimation of the average speed of the moving vehicles, the total volume and the road's occupation percentage value is being performed. Most of the devices are located among the center of the city of Thessaloniki and along one of the busiest arterial roads in the city (Tsimiski Street). RCM infrastructure is being updated, in order to produce more accurate and usable data. The FCD recording mechanism is more robust, thus	CERTH-HIT & RCM & Taxiway	Derivation of hourly demand from distribution of traffic OD "correction" (TFlowFuzzy) Estimation of average speed as a proxy of the traffic status in the road network.

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Data source	Description	Provider	Role
	this data source is given a higher priority in comparison to the others.		
Taxi Service Demand Data	Using the status of the taxi FCD, the trips done by half of the taxis in Thessaloniki (and booked by phone or a dedicated app) are recorded. In addition, empty trips are also recorded aiming at analysing taxi drivers' behaviour when looking for a ride.	CERTH-HIT & Taxiway	Taxi OD matrix extraction
Bike-sharing Data Supply & Demand	Data from the usage of the bikesharing system of Thessaloniki (e.g. bike availability per station, rental information).	Brainbox Technologies S.A.	Trip generation model, calibration of models OD matrix for regular commuters with bike
Social Media Data	Public check-in data is being automatically collected via the Facebook Graph API in 30 minutes interval (customizable). The area of interest (e.g., Thessaloniki, Greece) is being properly divided into smaller grid segments, and a request for check-in events is being performed for each segment's spatial centroid via the Facebook developers API. With this method, the total number of check-ins per place is being obtained. The absolute number of the check-in events is calculated after deducting the number of check-ins returned by the same procedure during the preceding execution of the algorithm.	CERTH-HIT	Validation of the parameters of trip generation model (number of employees - attraction)
Points of Interest	A significant number of Points of Interest (POIs) in Greece and Thessaloniki (in greater detail) have been collected in the framework of relevant projects carried out by HIT during previous years. The datasets consist of information such as the POI's category, physical location, the contact details etc. The data is properly organized and indexed to allow end users and content administrators to perform search queries in an easy and effective manner.	CERTH-HIT & Municipality of Thessaloniki	Validation of the parameters of trip generation model (number of employees - attraction)
Other Public Transport Data	GPS data from the Public Transport bus fleet of the city is available for a 1-month period	CERTH-HIT	Calibration of the public transport model

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Data source	Description	Provider	Role
Public Transport Schedules and Lines	CERTH-HIT collects publicly available data about the schedules and timetables and the public transport network infrastructure (locations and names of bus stops). The data collection and refreshment are repeated every month.	CERTH-HIT	Public transport supply introduction in the models
Demographic Statistics	Socio-economic data is available both at aggregated and disaggregated levels	CERTH-HIT	Projection of sample to the population and cross classification analysis (regression model)
Parking Data Supply	Through last years, CERTH-HIT has collected and analysed information about the parking status and driver's parking behaviour on major roads in districts of the city of Thessaloniki. The datasets include general information about the parking slots availability, their physical location, their type (legal, illegal, for disabled persons, for loading/unloading only etc.) and computed statistics about the observed parking duration during the conduction of the studies. In addition, the municipality has parking policy in the city centre in GIS format.	CERTH-HIT & Municipality of Thessaloniki	Estimation of egress time for car in the city centre of Thessaloniki (used as parameter of the mode choice model)
Taxi Service Supply Data	Half of the taxi fleet of Thessaloniki is being monitored by CERTH-HIT, which enables analysis on how taxis operate in the city (taxi stops, time at stop, vehicle in queue, empty trips...)	CERTH-HIT & Taxiway	Calibrate the taxi model of the city (mode choice)
Weather Data	Historical weather data for Thessaloniki since 2013 (temperature, wind speed and orientation, light-sun conditions, precipitation, humidity, cloud coverage)	CERTH-HIT	Associate extracted OD matrices and congestion level with weather
Car Ownership	Aggregated values	CERTH-HIT	- Car availability density
Income statistics	Aggregated values	CERTH-HIT	Cross classification analysis (regression model)
Labour/Unemployment statistics	Aggregated values	CERTH-HIT	Cross classification analysis (regression model)

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Data source	Description	Provider	Role
Business statistics	It includes information that can help to assign the number of jobs per transport zone.	Business data from ICAP database	Assignment of the spatial location of companies to the zones of the models. Estimation of the number of employees (attraction model)

5.3.2 Data sources explored within MOMENTUM case

Table 17 – Data sources to be explored within MOMENTUM project in Thessaloniki

Data source	Description	Provider	Role
Land Use, Sociodemographic and Car Ownership Data	A fusion of three datasets described in Table 16.	CERTH-HIT & Municipality of Thessaloniki	To be used to extract population's characteristics of interest, including its density. It will enable a more accurate analysis of where the vehicle-sharing and DRT services should be provided.
Mobility Surveys	As described in Table 3.	CERTH-HIT	To be used to extract population's characteristics of interest, including modal split and behaviour, which will contribute to planning and to the estimation of potential demand for the services (modal split/mode choice).
Travel Time Data	As described in Table 16. Both FCD and Bluetooth sensors methodologies will be considered.	CERTH-HIT & Taxiway	To be used to extract congestion levels and commuting time, to calibrate the cost function of each mode/service (needed for the mode choice) as well as the assignment models.
Traffic Data	As described in Table 16. All available methodologies and mechanisms will be utilized in combination, to maximize network coverage.	CERTH-HIT & RCM & Taxiway	To be used to extract congestion levels and commuting time, to calibrate the cost function of each mode/service (needed for the mode choice) as well as the assignment models.

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Data source	Description	Provider	Role
Taxi Service Supply and Demand Data	As described in Table 16.	CERTH-HIT & Taxiway	To be used for mode choice calculation (cost function for taxi mode) and obtaining and validating O-D matrices for taxi services. To optimize the distribution and rebalancing of ride-sharing vehicles within the city.
Bike-sharing Data Supply	As described in Table 16.	Brainbox Technologies S.A.	To be used for the provision of bike sharing services, and estimation of the demand for such a system.
Car/Moto-Sharing Data Supply	Spatio-temporal data of available for rental e-scooters in the city of Thessaloniki, recorded at five to ten minute intervals	CERTH	To be used for the provision of e-scooter sharing services, and estimation of the demand for such a system.
Bike-sharing Data Demand	As described in Table 16.	Brainbox Technologies S.A.	To be used for the estimation and the validation of OD matrices for bike-sharing mode.
Car/Moto-Sharing Data Demand	By processing the sequence of locations for each shared e-scooter in the city of Thessaloniki, the completed trips are extracted.	CERTH	To be used for the estimation and the validation of OD matrices for e-scooter-sharing mode
Public Transport Schedules and Lines	As described in Table 16.	CERTH-HIT	To be used to extract PuT KPIs, including vehicle, passenger and seat kilometres, fuel consumption, emissions, LoS (waiting time, vehicle occupancy…) for calibrating/validaitng the PuT model as well as for analyzing the potential DRT services to be provided.
MaaS Data Supply	Data collected by MaaS application on users' trips.	CERTH-HIT & Taxiway	To be used for O-D matrices calculation and users behaviour modelling for an existing MaaS

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Data source	Description	Provider	Role
			(ride-sharing) application in the area.
Parking Data Supply	As described in Table 16.	CERTH-HIT & Municipality of Thessaloniki	To be used for estimating part of the costs of using private vehicles (mode choice) and the planning of distribution and rebalancing of shared vehicles within the city as well as for determining the location of potential charging points for EVs.
Parking Data Demand	As described in Table 16.	CERTH-HIT & Municipality of Thessaloniki	This dataset is not yet fully available but it will be used in the future for: - Supply side of the models

5.4 Transport models

5.4.1 Current transport modelling tools

There are a number of macroscopic, mesoscopic and microscopic models that cover the metropolitan area of Thessaloniki (and beyond).

5.4.1.1 Macroscopic transport models

5.4.1.1.1 CERTH/HIT model

CERTH/HIT has developed a **4-step multimodal[3] macroscopic traffic simulation model of the detailed large-scale network of the agglomeration of Thessaloniki** since 2010. The model is developed in VISUM 15.0. The model has been continuously updated since with data –concerning both the supply and the demand side - collected through various research and national projects, the latest of which being the Sustainable Urban Mobility Plan of the Municipality of Thessaloniki (2017-2019).

The **supply** side of the **road** transportation model includes 47,816 **nodes** (445 of them being signalized) and 52 **main nodes**, which contain detailed information about the geometry, permitted movements, control type and signal timing, and 137,920 directed **links** (with a dedicated Link ID attributed to each direction), bearing geometric (length, location in the network) and traffic related characteristics (i.e. number of lanes, free flow speed, capacity, direction, permitted modes, existence of dedicated lanes for bicycle or bus). Links open to private vehicles (cars, taxis) are classified in 7 categories, depending on their capacity and free flow speed. Each road category has a unique Volume-Delay function (BPR). Unique **turning** movements containing at least one transport mode other than walk are counted to be 124,277, while **main turns** are counted to be 770. Turns and main turns contain spatial

[3] The model simulates car-public transport trip chains (Park&Ride situations)

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information (from-via-to node id, turn direction, turn angle) and traffic characteristics information (permitted turns, rules). Figure 11 shows the road network introduced in the model.

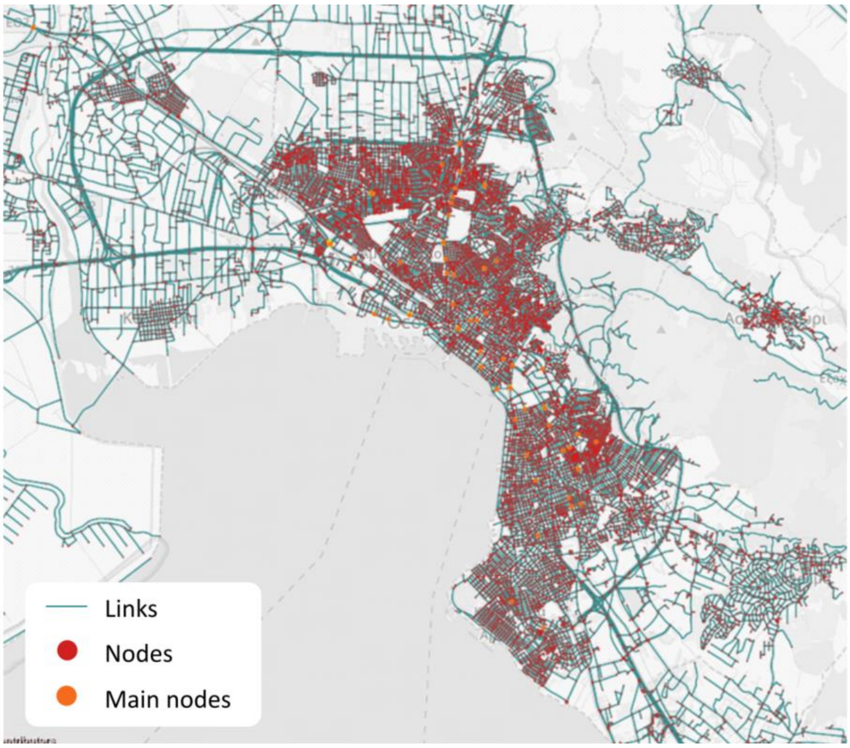

Figure 11 - An example of the road network (supply side)

The **zonal system** of the model consists of 339 traffic analysis **zones**, 328 of which are used for describing the metropolitan area of Thessaloniki, while the rest are external zones. Indicatively, the Municipality of Thessaloniki is covered by 125 zones. A total of 4,256 **connectors** are used for connecting zones to physical nodes of the road network, according to their accessibility index, avoiding connections with nodes of high hierarchy links. Figure 12 shows the model zoning.

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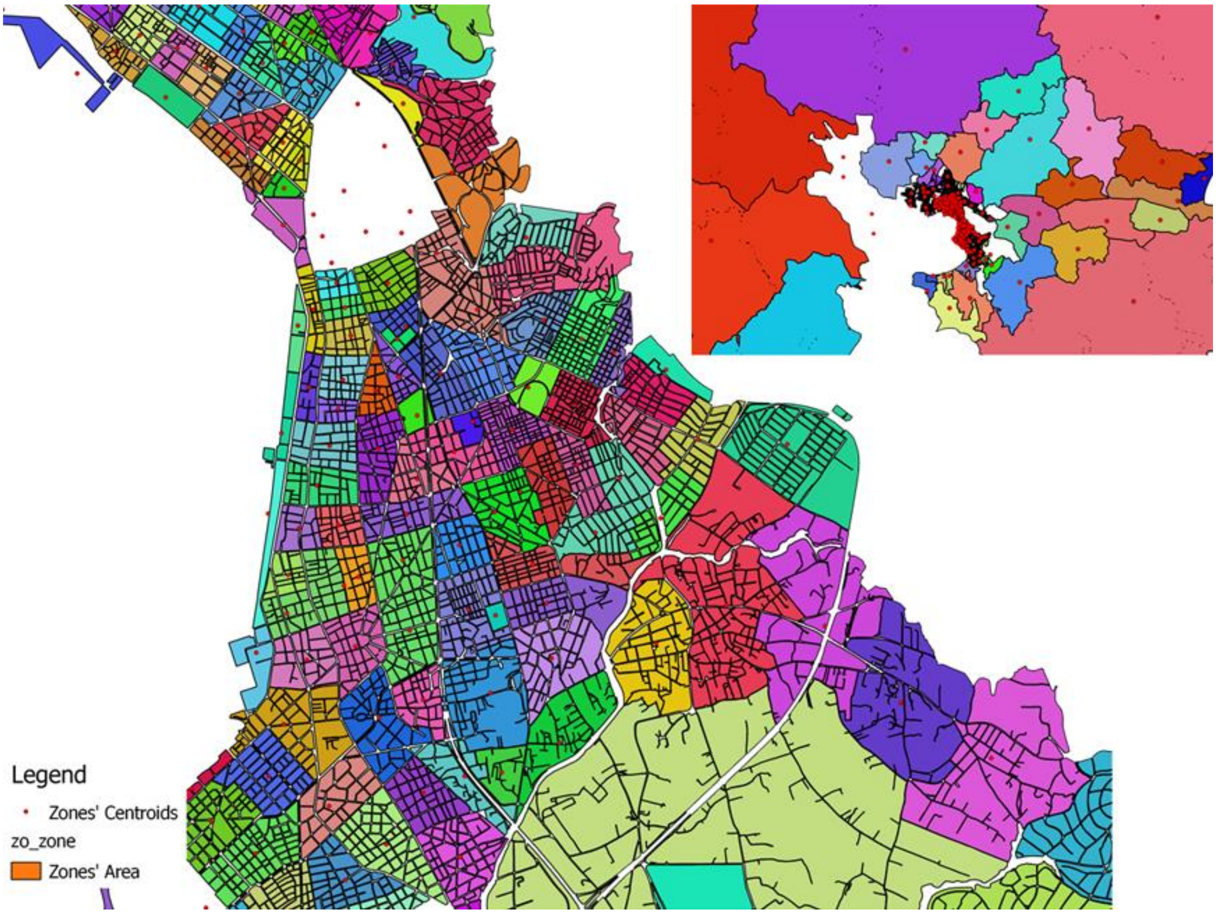

Figure 12 - Illustration of traffic zones

The **public transport supply** model includes 74 bus **lines**, 234 bus **line routes** and 3,450 **stops** (with their accompanied stop areas and stop points)**.** Currently, the public transport network of the metropolitan area of Thessaloniki consists only of buses, but future scenarios containing the subway network (2 lines to be delivered by 2023), sea public network, light railway network and tram network have also been developed by CERTH/HIT. Figure 13 shows the modelled bus network.

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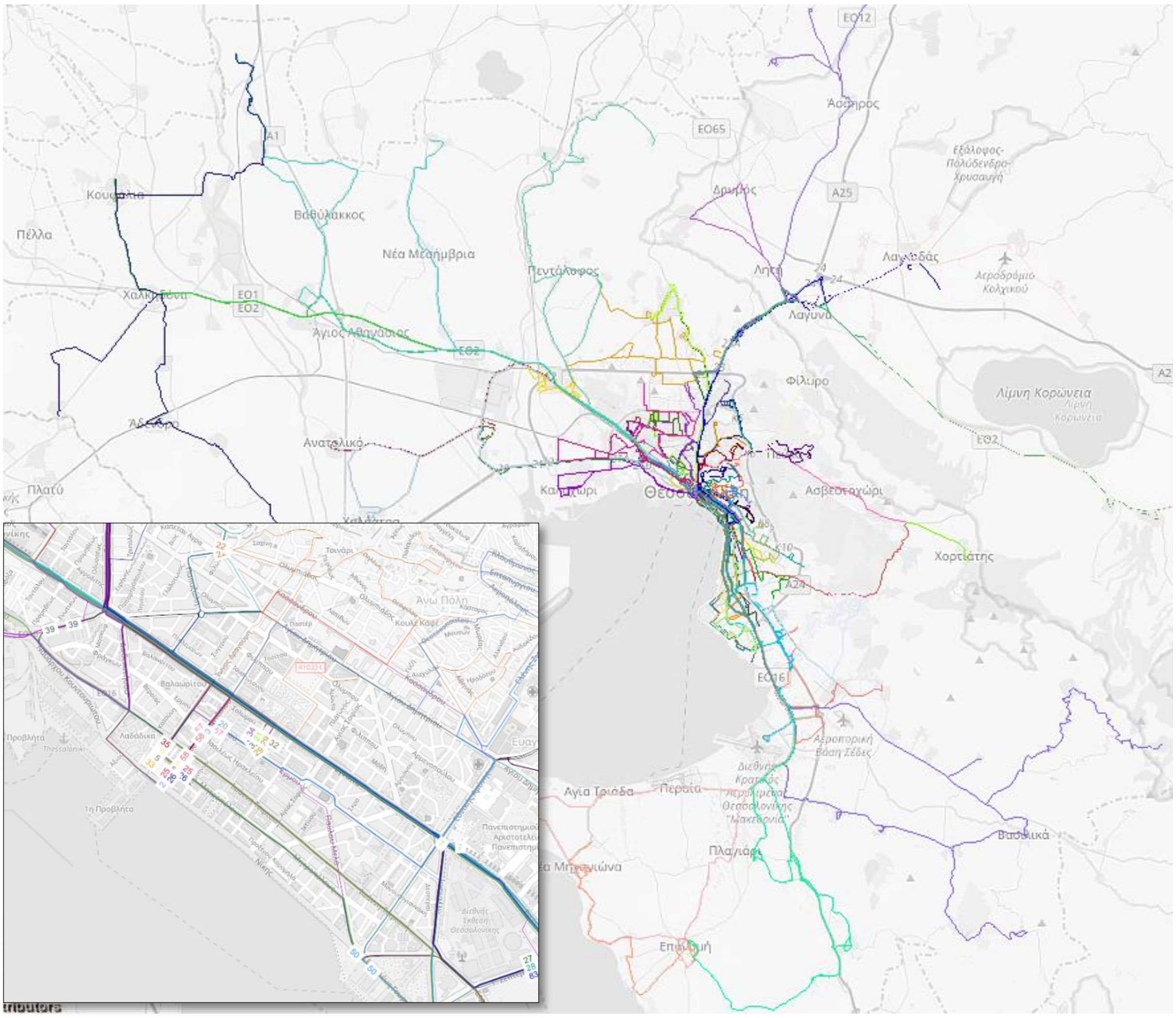

Figure 13 - Bus lines of public transport supply model

The most recent (2017) main data sources for **demand** estimation included telephone surveys and stated preferences surveys (for a sample of around 11,000 participants), as well as traffic counts in 40 network points (on a 24-hour basis) and 20 road intersections (data provided by the Municipality of Thessaloniki). Real time traffic counts were also used from CERTH/HIT's network of Bluetooth sensors, located along main arterial roads of the city of Thessaloniki, and from Floating Car Data (FCD) of taxi fleet of around 1,000 vehicles (data also received and processed from CERTH/HIT).

Apart from these, population related characteristics (from the Hellenic Statistical Authority - HSA) were also used for the projection of the sample to the population. Population data from the latest census (2011) were provided per city block level and aggregated to zone level. Data were projected to 2017 based on HSA's projections. Moreover, a database from ICAP – an online directory of companies – was used for a first spatial allocation of number of job places to the models' zone (based on the postal code).

The estimation of the **trips produced and attracted** per zone was conducted using linear regression model. Cross classification analysis of the population was also used based on sociodemographic characteristic (male – female, financial active and non-financial active), while the following trip types were considered:

- Home Based Work (HBW)

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- Home Based Other (HBO)
- Home Based Education (HBE)
- Home Based Shopping/Leisure (HBSL)
- Non Home Based Work (NHBW)
- Non Home Based Rest (NHBR)

In total, 24 **production** equations were developed, using as input data the trip start position and start trip type from the diaries, the zone's population and zone's boundaries. Figure 14 shows a scheme of the trip production model.

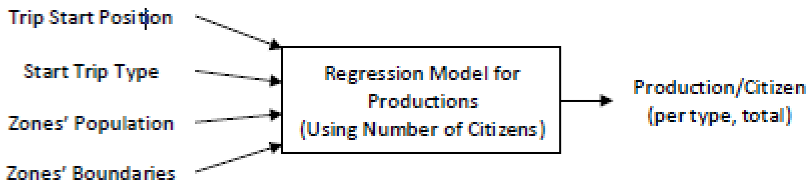

Figure 14 - The input and output data of the production model

Likewise, the **attraction** model includes 24 linear equations, using the number of jobs estimated for each zone. Locations of health, education and public administration activities were also considered for the update of the existing database of job places. A methodology for the estimation of the job places per zone has been also developed by CERTH/HIT, considering the employees' movements from the trip diaries and the work active population of each zone. A data-driven model for the validation of the results has been also created by CERTH/HIT, correlating land use data with the number of jobs. Figure 15 shows a scheme of the trip attraction model.

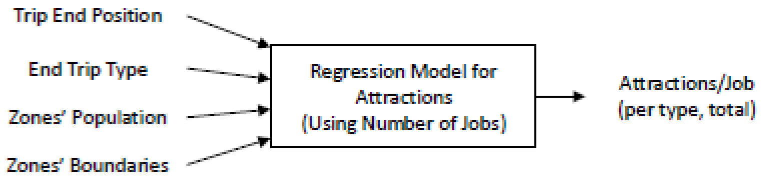

Figure 15 - The input and output data of the attraction model

For the **distribution** of the trips between zone pairs a gravity model has been used for each one of the 24-demand stratum[4].

The **mode choice model** was developed based on the stated preference questionnaires and on random utility maximisation. Multinomial Logit Models were developed using the R programming language and more specifically, with the use of mlogit library. Market segmentation techniques were applied. In total, 24 market segmentations were developed, using statistically significant parameters per sex, trip purpose and the socioeconomic (financial active/inactive) traveller's characteristics. The mode choice model has been validated through statistical and

[4] A demand stratum is the basic object in VISUM for creating trip generation, distribution and mode choice. It links the activity to the person groups (i.e. Home_Based_Work Financial Active Female)

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logical tests of the mathematical equations, comparison of the model's results with the results from the household survey and sensitivity analysis. The mode choice model includes private car, taxi, walk, bicycle and public transport.

The daily resulting OD matrices per mode have been temporally segmented in the peak hour interval (08:00 – 09:00) based on the profile provided by previous RSS survey and the most recent household survey. Approximately an 8% of the total daily demand is attributed to the morning peak hour.

On the private transport **assignment** (cars and taxis), the user equilibrium traffic flow estimation, based on **Wardrop's user equilibrium principle**, has been solved with an implementation of the Linear User Cost Equilibrium algorithm, terminating at pre-specified goodness-of-fit criteria for the resulting traffic volumes. The public transport assignment was based on the bus lines headways.

This model has been applied in several projects:

- EOX project (2009-2012). "Intelligent urban mobility management and traffic control system for the improvement of the urban environment quality in the central area of Thessaloniki's agglomeration". The project enabled the data collection (historical/real) for the metropolitan area of Thessaloniki from various sources (surveys, traffic counts, inductive loops), the development of the supply side of the macroscopic model of CERTH/HIT, the development of traffic estimation and prediction models and, eventually, the provision of a suite of services, from routing services and traveller information services to dynamic estimation of traffic conditions and incident management. www.mobithess.gr
- Study for the Sea Transportation of the city of Thessaloniki (2011). The model tested future scenarios including sea transport network and subway network as public transport options further to buses.
- "Study for the impacts of pedestrianization of a road segment of Agias Sofias road" (2012). The study used a sub-network of the detailed model of the metropolitan area of Thessaloniki (3364 links, 1131 nodes, 95 zones), covering the historical city centre, in order to evaluate different scenarios of pedestrianization of a specific road.
- Study for the system of controlled parking system of Thessaloniki (2012). The model evaluated different pricing scenarios and scenarios on the geographical coverage of the system.
- Study of the west "City Train" (part of the RAIL4SEE South East Europe project, 2012-2014). The aim of the study was to investigate the feasibility of a new suburban rail link between the port of Thessaloniki and the western suburbs of Thessaloniki's metropolitan and industrial area.
- The Sustainable Urban Mobility Plan of the Municipality of Thessaloniki (2017-2019). The SUMP enabled the data collection for the metropolitan area of Thessaloniki from various sources (surveys, traffic counts), the update of the existing macroscopic model of CERTH/HIT and the update of traffic estimation and prediction models. The model application in SUMP included scenario testing, which included new modes of transport for future horizons (2023, 2028 and 2028), also modelling future Park & Ride facilities.

5.4.1.1.2 Organisation of Planning and Environmental Protection of Thessaloniki model

The Organisation of Planning and Environmental Protection of Thessaloniki developed a **4-step model** (static, trip based) for the "General Study of Transport and Traffic for the Urban Area and the Surroundings of Thessaloniki", which was conducted from 1998 to 2001.

It was developed in EMME/2 and based on several surveys, counts and inventories, contacted for the purposes of the study, namely: household survey, stated preference survey, traffic counts, travel time measurements of specific routes, road side survey, inventory of the parking characteristics, inventory of the road infrastructure and characteristics, freight transport survey, taxi movement survey and public transport survey and measurements. The study area of the model included the urban and peri-urban area of Thessaloniki (1.100 km^2) and 316 traffic

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zones. The zonal system of the model was used as a basis for the development of the zonal systems of the other models of the area. The road supply model includes 1335 nodes and 5120 links (covering 9 different road types), while the public transport (bus) supply models includes 52 bus lines.

The study aimed at analysing the characteristics of peoples' movements and the alternative forms of transport infrastructures and policies, in order to optimize the operation of the transport system in the greater area of Thessaloniki, within the context of Thessaloniki's Regulatory Plan. Different scenarios of future transport infrastructure and organization development were formulated and analysed.

5.4.1.1.3 Transport Authority of Thessaloniki (TheTA) model

The model of TheTA has been developed in VISUM (unknown edition), between 2008-2011, as part of the study "Estimation of the Socioeconomic Impacts due to the Extension of Metro Line to Kalamaria". A **4-step model** (static, trip based) has been developed for the metropolitan area of Thessaloniki, which includes car, taxis, and public transport. No further data are available concerning the characteristics of supply and demand.

5.4.1.1.4 Aristotle University of Thessaloniki (AUTh) model

AUTh has developed in VISUM (unknown edition) a **4-step macroscopic** model (static, trip based) for the metropolitan area of Thessaloniki. The network or sub-networks of the model have been used for academic purposes. Cooperation with CERTH/HIT was established in most of the academic studies (see below), for provision of supply and demand data. Indicatively, the following applications of the model are mentioned:

- Thessaloniki's urban area (contiguous built-up area around the Municipality of Thessaloniki). The model has been developed in VISUM with 19.914 links, 6.600 nodes, 173 zones and 1400 connectors. The development of the network was based on GIS data provided from CERTH/HIT. The model was used for a "Sensitivity Analysis of Thessaloniki's road network traffic conditions for different precipitation intensity scenarios".
- Thessaloniki's city centre. The model includes 894 links, 448 nodes and 5 main nodes, 48 zones and 326 connectors. The hierarchy of the road network reaches down to secondary collector roads. The model was used for "Sensitivity analysis of supply-demand relations using different network charging algorithms" (2016), "Planning and design of a cycling network in the city of Thessaloniki. Tests of feasibility and functionality with the use of a traffic assignment model applied in urban networks" (2015), "Testing soft mobility projects in the center of Thessaloniki" (2014)
- East urban area of Thessaloniki. A macroscopic model has been developed and used for the academic studies "Application of traffic simulation software in an urban environment" (2014) and "Formulating urban traffic mobility with the use of macroscopic simulation models" (2012). Network road supply has been coded down to the level of collector roads, including a small number of local roads, and consists of: 3704 links, 1230 nodes (out of which 150 are signalized), 13 main nodes, 112 zones and 664 centroids. Demand data of the morning peak hour (08:00 – 09:00) have been provided from the "General Study of Transport and Traffic for the Urban Area and the Surroundings of Thessaloniki" (1998-2001). For the calibration of the model traffic flow data were provided by CERTH/HIT.

5.4.1.2 Relevant micro- and mesoscopic transport models

5.4.1.2.1 Thessaloniki's city centre model

The **microsimulation traffic model** created for the city centre of Thessaloniki was set up in AIMSUN (advanced edition 8.2) and consists of 854 sections, 290 intersections (91 of which are signalized) and 104 connectors. The following section attributes were defined: number of lanes, capacity, maximum permitted speed, direction of traffic, permitted modes, radiant and pedestrians' crossings. Detectors were used to simulate the location of real traffic counts. Dedicated bus lanes have been also simulated. Figure 16 shows the network of this model.

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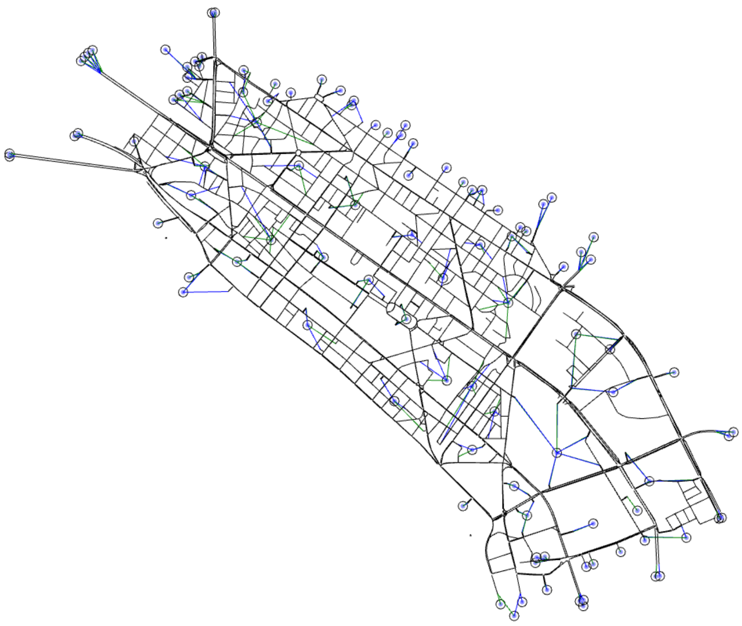

Figure 16 - The model of the city centre of Thessaloniki, simulated through AIMSUN

The model includes 4 modes: private cars, taxis, light freight vehicles, small buses and motorcycles. Traffic demand is drawn from CERTH/HIT's macroscoping traffic model of the metropolitan area of Thessaloniki.

Model applications include the study of the pedestrianization of Agias Sofias St. (CERTH/HIT - 2017). The microscopic model tested three pedestrianization scenarios (partial or total pedestrianization) of a specific road in the city centre of Thessaloniki, as per their impact in the wider area of the historical city centre. Static assignment was used.

5.4.1.2.2 Signalized Urban Arterial Corridor - Vasilisis Olgas St.

A major axis in the city of Thessaloniki (Vasilisis Olgas St., 6.2 km length) has been simulated and two scenarios for studying the on-street illegal parking have been developed and tested (Figure 17).

The **microsimulation traffic model** was set-up in AIMSUN (advanced edition 8.2). The model introduced an approach in AIMSUN locations and duration of double parking phenomenon using reserved lanes plus incidents to model the burden that is caused to adjacent lanes for as long as parking maneuvers take place.

The representation of the road axis within AIMSUN consists of 379 road sections, 86 intersections, 31 of which are signalized and includes information about road direction, number, width and functional use of lanes, capacity, maximum permitted speed, slope, type of vehicles using the road, bus stops locations, on street parking locations, nodes geometry allowed turns, signage, traffic control, pedestrians' crossings, and traffic signals timing.

Information about the 9 bus lines of public transport serving the axis was also included in the model. For each bus line, information about the road sections that it runs, the bus stops where it stops, the detailed timetable for the peak hour and the average bus stop duration was included.

Traffic demand was taken from CERTH/HIT's macroscopic traffic model of the metropolitan area of Thessaloniki. The data refer to the morning peak hour (8:00-9:00) and was given in 6 Origin/Destination matrixes, for the 6 different types of vehicles using the road (cars, taxis, motorbikes, buses, trucks and public transport buses) and used 92 centroid locations to allocate the demand on the network.

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To simulate double parking, 'incidents' were used to specify where, when and how long double parking events along the axis occur based on the results of the data collection. In addition, extra 'incidents' were inserted to model the burden caused to adjacent lanes, that includes time for identifying a sufficient gap between already parked vehicles, the vehicle speed reduction and the necessary manoeuvres to park. A time of 15 secs (± 5 secs) was considered as the mean time a driver needs for this procedure.

The model was calibrated to represent the traffic conditions as accurately as possible. Data from traffic counts in 8 nodes and 2 sections along the axis were used for this purpose as well as data about average speed and travel time of taxis and public transport buses along the axis taken from their fleet monitoring centres.

 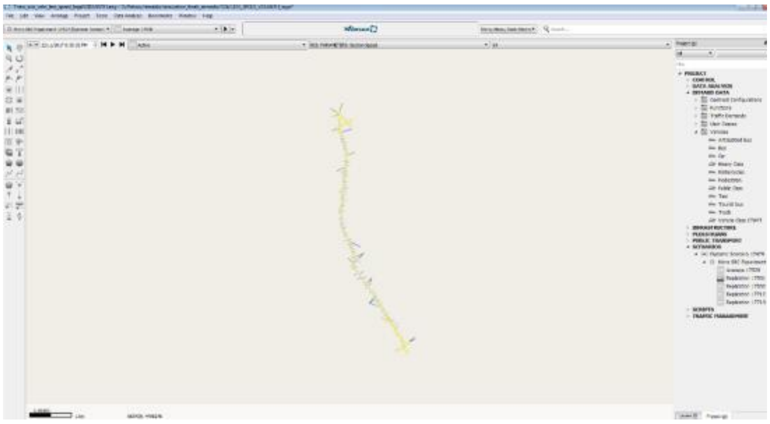

Figure 17 - The location of the study axis in the city of Thessaloniki (left) and the axis simulated in AIMSUN software (right)

The simulation time was set at 1 hour, recording data every 15 minutes and 5 replications of each scenario were performed according to the software guidelines. For the estimation of the environmental/energy indicators, the integrated in AIMSUN software microscopic emission model has been used that relates vehicle emissions with the instantaneous speed and acceleration of the vehicle.

Model applications include Project Remedio, which aimed at assessing the impacts of the phenomenon of double parking along an urban axis of Thessaloniki. Two different scenarios were modelled; one where only legal on-street parking along the axis is considered and a second one, representing the actual situation, where also a number of double-parking events were modelled. The interaction with the traffic that the axis serves was studied.

5.4.1.2.3 Signalized Urban Arterial Corridor - Tsimiski St. – Cooperative C-ITS

A **microscopic simulation model of an urban arterial corridor** (Tsimiski St.) in the city of Thessaloniki, Greece, was developed with the use of the microscopic traffic simulation tool Aimsun (Version 8.1.2 – R37672 x64). The micro-model was used as a testbed to evaluate the performance of a Green Light Optimal Speed Advisory (GLOSA) service which was replicated in Aimsun via the development of a corresponding Application Programming Interface (API).

The simulation network was spatially extended around the urban arterial corridor to ensure realistic vehicle arrival patterns in the study area. Its total length is 15 km and it encompasses 26 signalized intersections which are controlled by pre-timed signal control plans. The GLOSA service is deployed separately on each signalized intersection approach of the examined simulation network. Side-street parking and seven public transport lines (along with their corresponding time plans) that cross Tsimiski St. were input to the model as well.

Demand was obtained from a macroscopic traffic assignment model previously developed in VISUM for the wider area of Thessaloniki. Field traffic flow data collected from traffic sensors located throughout the road network of

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Thessaloniki pertaining to a one-hour morning peak period (8:00–9:00am) of a typical weekday (Wednesday, December 11, 2013) were input into the macroscopic model, which executed the traffic assignment and produced the demand pattern (OD matrix, path assignment) necessary for the “loading” of the microscopic traffic simulation model. Traffic composition in the central business district (CBD) of Thessaloniki (where the urban arterial corridor is located) was obtained from actual traffic data. The vehicular fleet along Tsimiski St. is comprised of 90% passenger cars, 5% taxis, 4% trucks, and 1% buses.

A thorough macroscopic calibration process was conducted to ensure the ability of the microscopic traffic simulation model to replicate actual traffic operations along the examined road network. Calibration parameters of the driver models of Aimsun (car-following, lane-changing, and gap-acceptance models) were adjusted for the reconciliation of field and simulated traffic counts. Field traffic data were obtained from several traffic detectors that monitor traffic conditions along Tsimiski St. The latter data contain traffic volumes, average time mean speed, and travel time information pertaining to the aforementioned simulated time period. Travel times along the urban arterial corridor ware estimated based on Bluetooth detector data. Field and simulated traffic counts were used for the conduct of the appropriate statistical test (GEH) to verify the validity of the simulation model.

5.4.1.2.4 Ring-Road of Thessaloniki

A **microscopic simulation model of the ring-road of Thessaloniki** was developed in the context of a bachelor’s degree thesis that was conducted at the Aristotle University of Thessaloniki (AUTh) with the collaboration of the Hellenic Institute of Transport/Centre for Research and Technology Hellas (HIT/CERTH). The model was developed to study the relationship between main parameters of traffic flow.

The model encompasses the eastern part of the ring road of Thessaloniki, sections of Egnatia street and the national road Thessaloniki – Giannitsa. The research focused on the relationship between fundamental parameters of traffic (flow and speed) using data produced from the application of the microscopic model in AIMSUN.

The **supply** side of the transportation model includes: 278 intersections, (21 of them signalized), 540 sections and 87 connectors.

The **demand** data needed for the development of the traffic model was based on 24 hour and hourly (peak hour: 10:00 – 11:00 am) O-D matrices, for private vehicle trips (car, taxi, heavy vehicles) and public transport (buses) and were provided by the CERTH/HIT. For the needs of this study, main bus lines that cross the study area have been selected and modelled.

The validation of the system was based on traffic counts provided through nine traffic cameras at specific locations on the east ring road of Thessaloniki.

Traffic assignment in the network was made with the use of static stochastic traffic assignment model, for which the principle of ‘stochastic user equilibrium’ applies. The ‘warm-up’ time of the network has been set to 15 minutes, as it was considered a sufficient time for the network to load and the demand has been set from the O/D matrices. Finally, statistical data export time has been set to 15 minutes.

Three different driving behavior modes – default, aggressive, passive – were examined. To achieve different driving behavior modes, the software’s parameters have been modified. These parameters were selected to change related to car-following model and lane – changing model. More specifically, modifications have been made in the following parameters:

- Sensitivity factor
- Give-way time
- Imprudent lane changing cases

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- Sensitivity of imprudent lane changing cases
- Reaction time
- Test incident scenarios in various locations

Also, for the three behavioral modes, 17 different demand scenarios were examined. In all cases, speed – flow diagrams were produced.

The supply side of the model included 243 sections and 119 intersection (3 of which being signalized) and has been codes with GIS geospatial information provided by CERTH/HIT. The geometric characteristics (number of lanes, direction of traffic) have been encoded for each section, as well as the geometry, permitted turns and type of signaling for each intersection.

Signal programs, traffic count figures and traffic composition have been also provided from CERTH/HIT's databases and inserted in the model. **Stochastic Route Choice Assignment** has been applied, while 15 minutes "warm up" time has been selected.

5.4.1.2.5 Simplified Networks – Hypothetical Demand Scenarios – Connected & Automated Driving

A few simplified simulation networks were developed with the use of the microscopic traffic simulation software **SUMO** to test algorithms dictating automated vehicle motion (ACC/CACC, lane changing, and control transitions). Hypothetical demand scenarios were input to the latter simulation models, and the traffic mix encompassed passenger cars, light goods vehicles, heavy goods vehicles and buses (where necessary according to scenario scope). Representative titles describing the developed simulation networks are provided below:

- Three-lane urban road with dedicated bus lane + road works
- Freeway merge segment
- Merging area of two two-lane highways
- Two-lane road + road works (urban & motorway roads)
- Two-lane motorway stretches + side-street parking spots
- Freeway diverge segment
- Three-leg signalized intersection + incident

5.4.1.2.6 Thessaloniki's multimodal urban and peri-urban arterial corridors (signalized)

Using the open source software for **microsimulation** SUMO (Simulation of Urban Mobility, CERTH/HIT currently develops the model for Thessaloniki's Urban Area. The model is to be used for assessing different policies of traffic management, coordinating the provision of C-ITS services and optimizing existing traffic signaling.

5.4.1.3 Summary of current transport models in Thessaloniki

The following table summarizes the existing models in the metropolitan area of Thessaloniki, the software used, the modal scope and modelling approach, as well as the network coverage and model usage.

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Table 18 - Existing models in the metropolitan area of Thessaloniki

Category/level of analysis	Software used	Network coverage	Modal scope	Modelling approach	Use
Macroscopic	VISUM	Urban and peri-urban area of Thessaloniki	Multimodal (car-public transport trip chains allowed)	Static	Thessaloniki's Sustainable Urban Mobility Plan (SUMP) “Intelligent urban mobility management and traffic control system for the improvement of the urban environment quality in the central area of Thessaloniki’s agglomeration” Study for the Sea Transportation of the city of Thessaloniki Study for the impacts of pedestrianization of a road segment of Agias Sofias road (sub-network of the city centre used) Study of the west “City Train”, testing the feasibility of a new suburban rail link Study for the controlled parking system of Thessaloniki, evaluating pricing and system's geographical coverage scenarios Estimation of the Socioeconomic Impacts due to the Extension of Metro Line to Kalamaria
	EMME/2	Urban and peri-urban area of Thessaloniki	Multi-class	Static	General Study of Transport and Traffic for the Urban Area and the Surroundings of Thessaloniki

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Category/level of analysis	Software used	Network coverage	Modal scope	Modelling approach	Use
Microscopic	AIMSUN	Thessaloniki's city centre	Multi-class	Static	Study of the pedestrianization of Agias Sofias St. Academic use
		Thessaloniki's ring road	Multi-class	Static	Academic use
		Vasilisis Olgas St.	Multi-class	Static	Remedio project - assessing the impacts of the illegal parking and re-designing the street
		Tsimiski St.	Multi-class	Static	Evaluate the performance of a Green Light Optimal Speed Advisory (GLOSA) service
	SUMO	Simplified simulation networks	Multi-class	Static	Test algorithms dictating automated vehicle motion (ACC/CACC, lane changing, and control transitions)

The main limitations for the city models are strongly related to the challenges identified by MOMENTUM, namely the need to integrate new mobility services and data collection methods. Cities are struggling with traditional data collection methods, as they are both time and money consuming. Common 'errors' related to these methods (i.e. household surveys conducted by telephone, thus reducing the credibility, representativeness of the sample, sufficient number of sampling units), but also lack of a dense network of inductive loops that could provide traffic counts on a 24-hour basis (that could also feed the validation of road supply characteristics) and phenomena like the illegal parking (and illegal double parking) that significantly affect the road supply (capacity) estimation, are all issues that can be considered relevant for the city case.

5.4.2 Transport modelling innovations within MOMENTUM case

The objective of Thessaloniki case study is to **improve the planning and decision-making process** for the introduction of resilient sustainable mobility schemes, with main emphasis in the integration of DRT, ride-sharing and vehicle sharing (micromobility, bike & electric car) mobility solutions towards MaaS in the agglomeration. The transport model that will develop within the MOMENTUM **will start from the CERTH/HIT model of the agglomeration of Thessaloniki**. Therefore, comparing the characteristics of the CERTH/HIT model with the scope of the case study of Thessaloniki, a range of novelties involving emerging mobility solutions are needed.

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5.4.2.1 DRT modelling

Reviewing the literature, it is found that in the most cases DRT services are provided to areas with a low population density and that the socioeconomic characteristics of the population influence the use of such services. The mobility disabled, the poorest, the youngest and oldest members of society as well as the women are the dominant users of DRT services [6]. This means that people who are more deprived are more likely to use DRT services. A possible explanation would be that these groups have limited access to private cars and thus, low percentage of car ownership.

Thus, the areas of agglomeration with low population density and high proportions of the above socioeconomic characteristics seems to be the most appropriate for the implementation of DRT services. Such areas could be identified based on the telephone and stated preference surveys performed in 2017. For the purposes of the case study DRT can be categorized into (i) flexible bus lanes which responds to changes in demand by either altering their route and/or their timetable and (ii) ride-sharing service where taxis will feed the perimetral bus stations. These two categories need to be modelled and addressed as two different scenarios in order to potentially evaluate their effect.

Based on the above characteristics of the area, DRT services will have better performance in the surrounding of the agglomeration, where the population density is low. Since the public transport network is not well structured in these areas, there is a lack of accurate data related to public transport lines and time schedules. The new model will focus on issues of accuracy of the data in these areas in order to capture issues of demand dispersion and modal split which are of high importance for the implementation of DRT services.

5.4.2.2 Ridesharing modelling

Ride-sharing schemes operates more efficiently either on large scale or in areas with high concentration on routes where demand is sufficient [7]. A large number of vehicles and users implies a sufficient percentage of demand and thus, an easier clustering of passengers who are going in the same direction at the same time.

Thus, using ride sharing data collected by the GALILEO4MOBILITY project, such as OD matrices and timetables of trips executed from suburban and peri-urban areas towards the city center and back, combined with the OD matrices collected through the recent telephone survey, ride sharing service will be modelled within these areas. A crucial point in the ride-sharing service modelling is the time and location flexibility of the users. This input will be crucial in cases that the critical mass is not sufficient for the clustering to be achieved. Therefore, one of the novelties of the new model will be to consider the flexibility of the users' time and origin/destination in order to create flexible routes served by taxis with a capacity of up to 4 people. Moreover, since the ride-sharing service aim to attract citizens that currently use their private car, the new model will also consider the relationship between the ride-sharing users and modal split.

Valuable inputs for the estimation of the users, the service's design (e.g. the number of the users per vehicle) as well as the appropriateness of the above areas for the implementation of the service (service coverage) will be emerged by the integration of ride sharing data in the transport model.

5.4.2.3 Vehicle sharing modelling

The current model does not include the possibility of using a vehicle sharing scheme of transport such as electric cars, bike sharing and micro-mobility. The new model will include this possibility. Electric cars schemes will perform better between the city centre and the suburban and peri-urban areas, while bike sharing and micro-mobility schemes will be limited to the city center and the suburban areas only. This will allow the services' planning to be modelled properly (vehicle distribution and balancing during the day and in the different areas of the city).

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One of the novelties of the case study is a new supply model including micromobility vehicles, bikes and electric cars (station-based or dockless, one way or round trip). Also, the relationship between the vehicle-sharing users and modal split should be considered in the new model.

Finally, one of the novelties that can be applicable in the new model is the issue of the trip chain. The current model includes two transport modes (private cars and public transport vehicles). This means that it does not consider the possibility of using different transport modes for each of the routes of a round trip (a citizen could not use his private car for a trip and then a bus for the return trip). The new model will include this possibility since someone can use the DRT service for a trip and then he can return using the car sharing service.

5.5 Integration of transport models in the urban policy cycle

5.5.1 Current integration mechanisms

The models developed for the urban and peri-urban area of Thessaloniki have fed the policy cycle processes and products in various levels.

5.5.1.1 National strategic planning

The study “Estimation of the Socioeconomic Impacts due to the Extension of Metro Line to Kalamaria” aimed at supporting the “maturity” of the project “Extension of Metro line to Kalamaria”. The project was included in the **operational programme "Transport Infrastructures, Environment and Sustainable Development" 2014-2020**. The programme sets out by differentiating the strategic needs of both the transport sector and the environment sector. For the transport sector, the investments aimed towards the needs of rail, road, maritime, air transport, intermodal transport and urban transport. The strategic objective of the programme for transport is the further development of the national transport system and the promotion of combined transport for the strengthening of the geopolitical position of Greece as the main European gateway and transport hub of the Balkans and the Mediterranean, sufficiently connected to the other Member States, most notably to the EU central development core.

The project “Extension of Metro line to Kalamaria” was included under Priority Axis 8 “Clean Urban Transport”. The main results anticipated is the drastic improvement of the public transport services and the increase of their attractiveness, thus competing to private car usage. The project is expected to provide a safe, quick and “clean” connection between the city center and the western urban areas of Thessaloniki and it was included in the operational programme as one of the major projects.

The national operational programme for transport also included funding for the “Elaboration / updating of further studies and technical studies for the project of west suburban railway of Thessaloniki” (under Priority Axis 8 “Clean Urban Transport”).

Study of the west “City Train” (part of the RAIL4SEE South East Europe project, 2012-2014). The aim of the study was to investigate the feasibility of a new suburban rail link between the port of Thessaloniki and the western suburbs of Thessaloniki’s metropolitan and industrial area.

The study for the Sea Transportation of the city of Thessaloniki (2011) was considered under the **operational programme “Increasing Accessibility” of the period 2007-2013**. The study aimed at examining the feasibility and sustainability of the new transport mode, with the overall aim of improving the connection between the city centre and the east urban and suburban areas. The study tested, through macroscopic modelling, different design, pricing and operational scenarios of the new sea transport network, as well as scenarios of re-structuring of the existing public bus operation. The study acted as a “maturity step” towards the actual implementation, as it also included cost and financial opportunities’ analysis, as well as the technical specification for the public procurement phase.

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5.5.1.2 Regional strategic planning

The model developed under the "General Study of Transport and Traffic for the Urban Area and the Surroundings of Thessaloniki" (1998-2001) was used to formulate a "**Strategic Plan**" for the development of Thessaloniki's transport infrastructure that would enable the hierarchy of projects and interventions to improve the conditions of pedestrians and vehicle traffic and the quality of the environment in the urban and peri-urban area of Thessaloniki. The study also focused on harmonizing the design of transport infrastructure in the urban and peri-urban area of Thessaloniki, considering the anticipated development of these areas in the future.

Several future scenarios were formulated and evaluated through the traffic simulation model, taking into account:

- Projects and policies prioritized as major infrastructural interventions (i.e. subway)
- National (relevant Ministries), regional (Organisation of Planning and Environmental Protection of Thessaloniki) and local (municipal) policies and strategies.
- The clear identification of the objectives of each scenario and the way the specific interventions address them.

Particular emphasis was placed in the promotion of sustainable modes of transport (public transport, bicycle, walking) and the limitation of private car use, as well as in addressing parking issues, upgrading quality of life and environment, creating a transport system friendly to pedestrians, elderlies and persons with mobility limitations and aligning with a polycentric approach (as this indicated by Thessaloniki's Regulatory Plan).

As part of the transport Strategic Plan of Thessaloniki, new modes were introduced, and more specifically:

- Thessaloniki's subway system
- The west intercity suburban railway
- The urban sea transportation

The above were eventually considered for funding (either for their development/construction and/or for further studies) under the national operational programmes of the periods 2007-2013 and 2014-2020 (see above).

5.5.1.3 SUMPs

As already mentioned, the metropolitan area of Thessaloniki consists of 11 Municipalities. The **Municipality of Thessaloniki,** being the largest one in population, is currently at the **final stages of its SUMP development.** Thessaloniki's SUMP started in 2017, with CERTH/HIT acting as the technical consultant of the Municipality and being responsible for the model development and scenario testing. CERTH/HIT's multimodal 4-step model (described in detail in section 5.4.1.1.1) has been integrated in scenario testing, identification of measurable targets, assessment of packages of measures and eventually definition of the integrated measure package and monitoring indicators. Results of the model scenario testing have been properly presented to and discussed with citizens and stakeholders. The SUMP development process has been also concluded for the Municipalities of Thermi and Ampelokipoi, without, though, scenario and measure testing via modelling. The rest of the Municipalities of the metropolitan area of Thessaloniki have already received funding from the Ministry of Environment[5].

[5] In 2016 the Green Fund of the Ministry of Environment launched a funding mechanism of euros 9 mil. in order to support the implementation of SUMP in 150 Municipalities (medium and large-sized). Overall, 168 Municipalities were invited to submit their application for funding. At the end, 153 Municipalities proceeded with the application.

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Thessaloniki's Integrated Transport Authority has also implemented (in 2013) the SUMP of the Metropolitan Area of Thessaloniki, in the framework of the ATTAC (Attractive Urban Public Transport for Accessible Cities) project. The Metropolitan SUMP of Thessaloniki covers 9 Municipalities and proposes 12 measures, mostly related to public transport. The Metropolitan SUMP of Thessaloniki used information from the model of the study "Estimation of the Socioeconomic Impacts due to the Extension of Metro Line to Kalamaria" for the analysis of the current situation and the identification of opportunities regarding the new subway system.

5.5.1.4 Small and medium scale local planning

With the use of macro- and micro-simulation tools specific (local) interventions were studied. More specifically:

- The pedestrianization of the street of Agias Sofias (a road located in the city centre of Thessaloniki) was studied as per the impacts of different pedestrianization scenarios in the traffic conditions of the surrounding area. The studies supported policy making towards the promotion of walking and cycling through the re-distribution of public space.
- The study of the controlled parking system of Thessaloniki evaluated different scenarios of geographical coverage and pricing, with the aim of finding the optimum solution in terms of providing suitable parking services for the city centre's visitors while reducing, at the same time, the share of private car (thus air pollution and congestion).

5.5.2 Transport models integration initiatives within MOMENTUM case

Transport modelling is already an important part of the policy making cycle since the CERTH/HIT's multimodal 4-step model (described in section 5.4.1.1.1) has been already integrated in scenario testing, identification of measurable targets, assessment of packages of measures and eventually definition of the integrated measure package and monitoring indicators of the Thessaloniki's municipality SUMP that is currently under the approval process by the municipal council of Thessaloniki. As described in section 5.4 there are a variety of transport models related to the city of Thessaloniki. One of the goals of Thessaloniki case study is the new model and the interactive decision support tool that will be developed within the MOMENTUM project to be certified by the municipality of Thessaloniki as the most appropriate for being used not only in the future SUMPs that will be developed for other municipalities but also in various decision-making processes.

After the achievement of the above goal, a critical step towards the delivery of effective transport systems will be the enhancement of the interaction between the various public and private stakeholders involved in the urban policy cycle across the functional transport area of the city. The desirable interaction will be achieved through the following principles-steps of knowledge management [8]:

- Socialization between the planners and the stakeholders involved in order to share experiences on specific mobility issues and to create and exchange tacit knowledge, brainstorming without criticism
- Externalization of the tacit into explicit knowledge and creating indicators and models that are easily understandable by the non-domain experts
- Combination of the explicit knowledge occurred from the previous stages looking to best practices and
- Internalization: a critical process of this stage is the consultation with stakeholders and the public in order to achieve the consensus in the community necessary to deliver sustainable outcomes. Consensus built among stakeholders will endure and provide the long-term strategic perspective required in the face of short-term political cycles. Through dialogue, planners could use the information to first optimize the model and later to develop more focused strategies.

Finally, the model **should be open and user friendly.** If it is necessary, it should be accompanied with a short description and information section in order the know-how to be transferred to the users.

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6. Conclusions

There are several conclusions that can be extracted from a comparative glance at the four case studies:

- Each of the four cities corresponds to a **different urban context in Europe**. This should improve the generalisability of the project outcomes. The differences lie not only in population size terms, but also in the territorial context. While Madrid and Thessaloniki are central municipalities in monocentric metropolitan regions, Leuven and Regensburg are relevant nodes in a polycentric structure. This have several implications in terms of mobility planning, both from a governance perspective (e.g. who should conduct transport modelling initiatives?) and from a technical perspective (e.g. which is the most appropriate study area for modelling mobility in the city?).
- Apart from the differences between the cities associated to the urban context, there are also **differences related to the familiarity with the use of decision support tools** in the field of urban transport. This is expected to ensure that MOMENTUM outcomes are useful for several "starting situations" with regard to the spread of transport modelling tools within mobility planning authorities. For instance, it can be seen that the close collaboration of CERTH and the municipality of Thessaloniki have facilitated the adoption of advanced models, while other cities have less experience in the field.
- There are opportunities for **cross-city analyses** in the project, since there are enough data to calculate and explore several mobility indicators for the four cases. For instance, this is the case of shared mobility adoption and use patterns (e.g. trip distances) or the impact of weather conditions in active mobility, including bikesharing.
- The project takes into account **most of the emerging mobility options** witnessed in its deliverable D2.1 "New Mobility Options and Urban Mobility: Challenges and Opportunities for Transport Planning and Modelling", since the data collected and the research objectives stated for the four cases cover several of these options: shared mobility, Demand Responsive Transport, vehicle automation, ridehailing, etc.

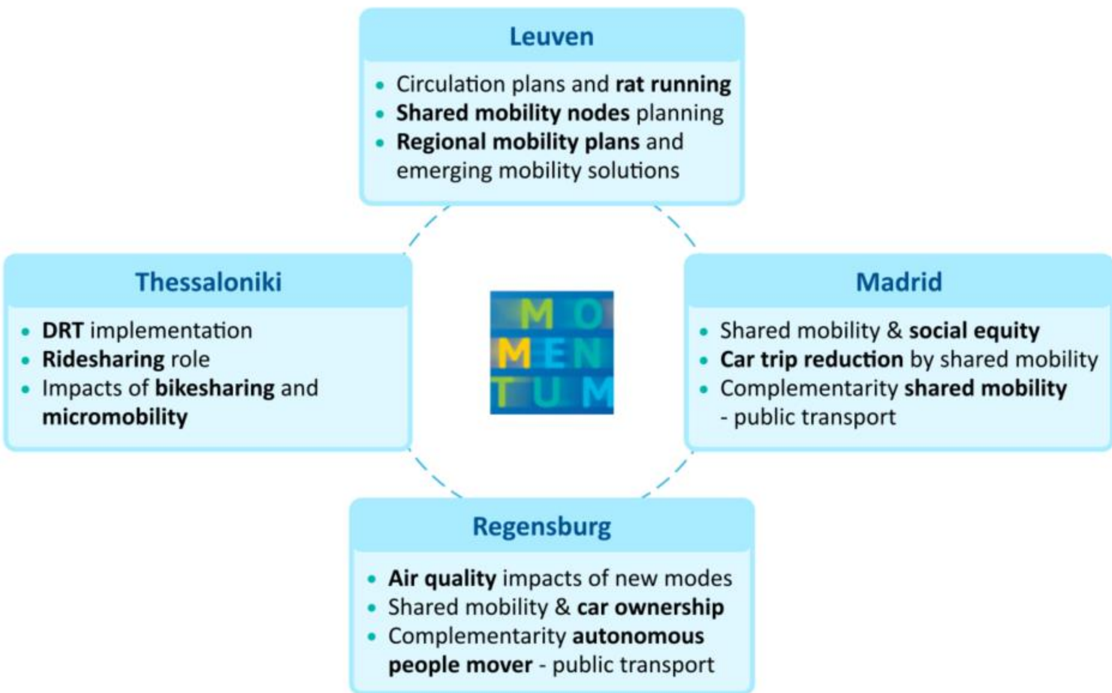

Figure 18 – Focal points in the four MOMENTUM Test Cases

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