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nuMIDAS: The New Mobility Data and Solutions Toolkit

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Abstract

The mobility ecosystem is rapidly evolving, with the rise of new stakehold-ers and services, accompanied by new ways for the generation, collection, and storing of data. In the nuMIDAS (New Mobility Data and Solutions Toolkit) project, we provided insights into what methodological tools, data-bases, and models are required, and how existing ones need to be adapted with new data. We started from insights obtained through (market) research and stakeholders, as well as quantitative modelling. A wider applicability of the project's results across the whole EU was guaranteed as all the research was validated within a selection of case studies in pilot cities, with varying characteristics, thereby giving more credibility to these results. Finally, through an iterative approach, nuMIDAS created a tangible and readily avail-able toolkit that can be deployed elsewhere, including a set of transferability guidelines, thus thereby contributing to the further adoption and exploitation of the project's results.

Keywords:

Intelligent traffic and mobility management, Data management

The nuMIDAS project in a nutshell

The mobility ecosystem is rapidly evolving, whereby we see the rise of new stakeholders and services. Examples of these are the presence of connected and automated vehicles, a large group of organisations that rally to establish various forms of shared mobility, with the pinnacle being all of these incorporated into a large MaaS ecosystem.

As these new forms of mobility offerings start to appear within cities, so do new ways in which data are being generated, collected, and stored. Analysing this (Big) data with suitable (artificial intelligence) techniques becomes more paramount, as it leads to insights in the performance of certain mobility solutions, and is able to highlight (mobility) needs of citizens in a broader context, in addition to a rise in new risks and various socio-economic impacts. Successfully integrating all these disruptive technologies and solutions with the designs of policy makers remains a challenge at current. let alone being able to analyse, monitor, and assess mobility solutions and their potential socio-economic impacts.

nuMIDAS, the New Mobility Data and Solutions Toolkit, bridged this (knowledge) gap, by providing insights into what methodological tools, data-bases, and models are required, and how existing ones need to be adapted or augmented with new data. To this end, it started from insights obtained through (market) research and stakeholders, as well as quantitative modelling. A wider applicability of the project's results across the whole EU was guaranteed as all the research was validated within a selection of case studies in pilot cities, with varying characteristics, thereby giving more credibility to these results. Finally, through an iterative approach, nuMIDAS created a tangible and readily available toolkit that can be deployed elsewhere, including a set of transferability guide-lines, thus thereby contributing to the further adoption and exploitation of the project's results.

nuMIDAS, the *New Mobility Data and Solutions Toolkit*, ran under the Horizon 2020 programme and was developed by a European Consortium, composed of 9 partners from 6 countries: Belgium, Czech Republic, Greece, Italy, The Netherlands, and Spain.

The project built on a distributed selection of case studies in four pilot cities to provide a geographic coverage of the EU: Barcelona (Spain), Milan (Italy), Leu-ven (Belgium), and Thessaloniki (Greece), as shown in Figure 1. All public deliverables can be readily downloaded from our website (https://numidas.eu/).

Figure 1 - Locations of the pilot cities.

From ideas and conceptual designs to toolkit deployment in pilot cities

General methodological approach

In order to achieve the project's outcomes, we took the following steps:

- Perform an assessment of the current trends
- Define advanced methods and tools
- Execute case studies in pilot cities
- Create a consolidated toolkit for stakeholders

Some of these steps ran in parallel, with feedback mechanisms involved in order to capture and process the latest developments and insights during the creation of the nuMIDAS toolkit.

A service-oriented architecture

In order to make sense, and to have a common and agreed upon language of terminology (see also Figure 2), the nuMIDAS project adopted a service-oriented architecture.

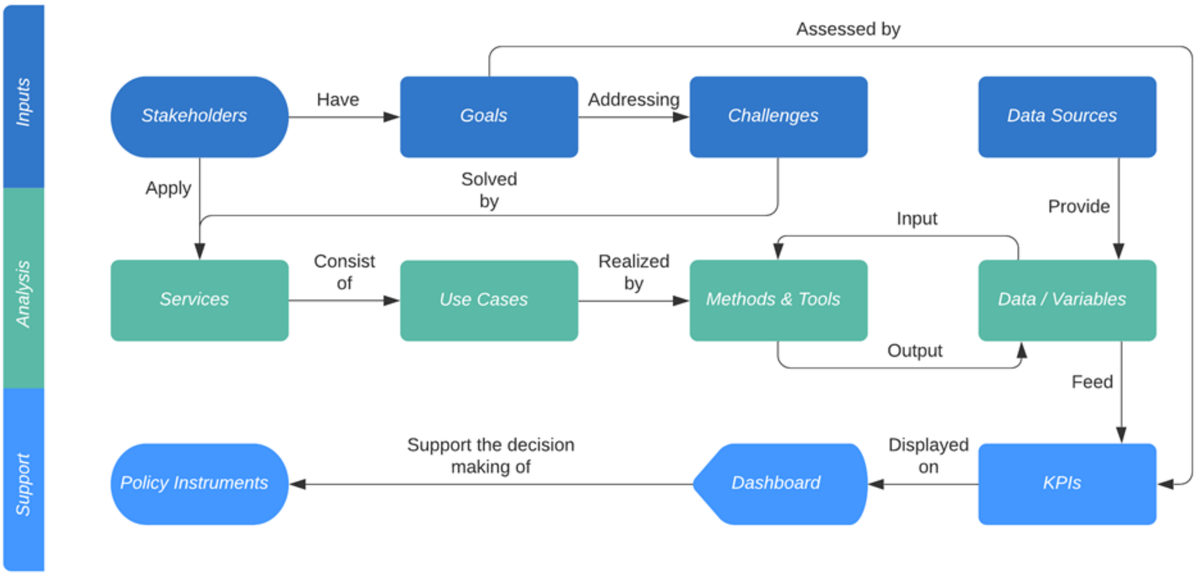


Figure 2 – The nuMIDAS model as a service-oriented architecture.

To this end we identified the services in scope (see also Figure 3). For each of them, a detailed overview of the state of the art was provided. After the individual analysis, a big picture was prepared to show links among the services and policy instruments. This big picture allows us to ensure unity in the produced output.

Selection of use cases

To successfully support transportation planners, researchers, and policy makers, emphasis was put on the harmonisation of the development of the toolkit. With this objective, a series of parameters was defined: extensibility, interoperability, minimisation of development and operational costs, reliability, and usefulness and user-friendliness of the toolkit. nuMIDAS provided high-level descriptions of the use cases, along with descriptions of problems which need to be addressed in the specific city(ies) and the technical approach to be adopted. In addition, we also provided UML mock-ups giving the visual representation of each use case approach, and capturing the entire process of a tool in combination with the interrelations with the involved actors.

In order to make the scope of each use case more understandable and tangible, they set the boundaries of the tool, the steps to be followed each time, and the requirements needed to move forward. An overview of what steps were followed to identify the use cases are shown in Figure 4.

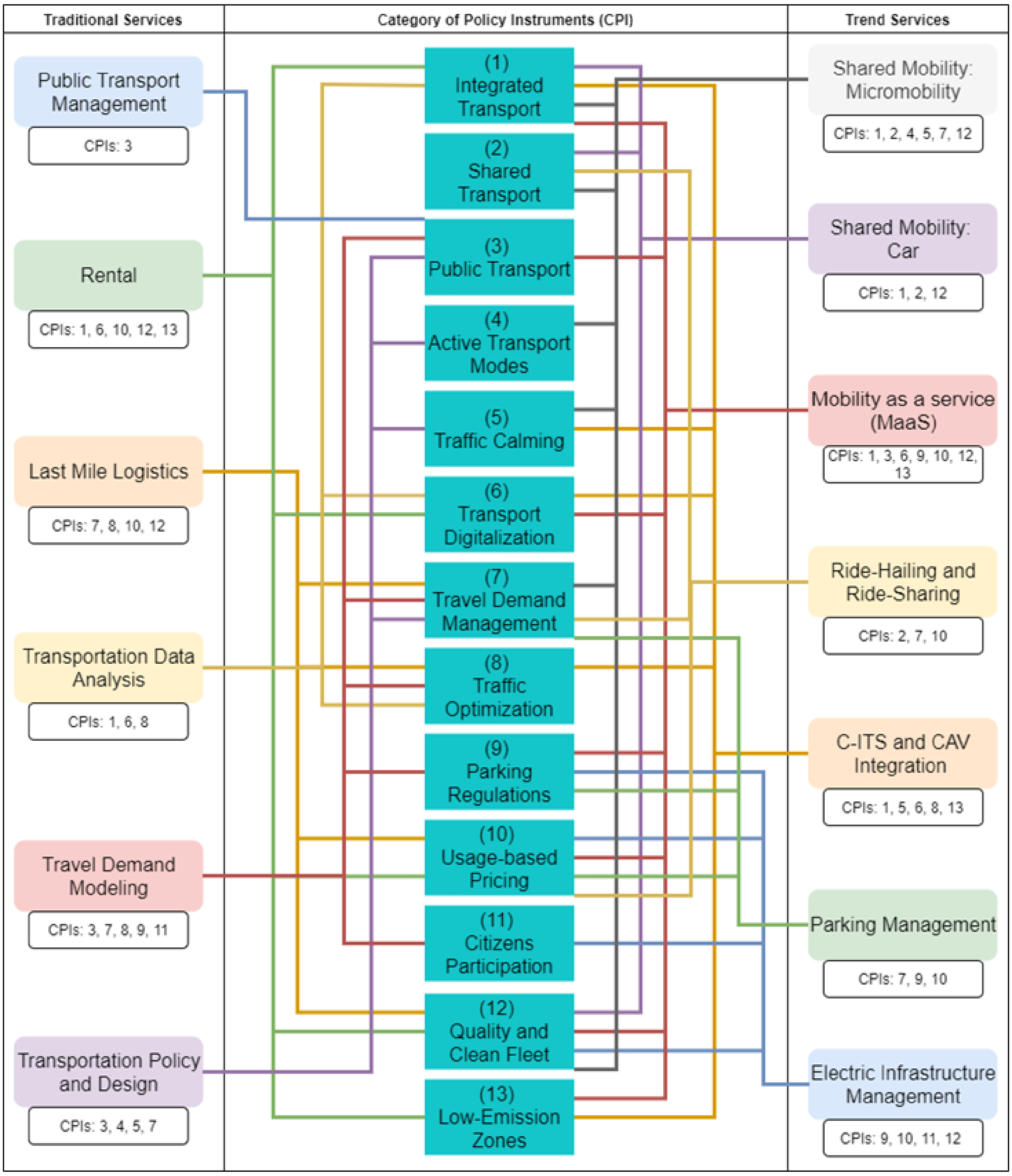


Figure 3 – The relations between services and categories of involved policy instruments.

Figure 4 – Overview of the processes followed for scoping the use cases in nuMIDAS.

Thanks to the requirements that emerged from the discussion and the interaction with the project pilot cities and relevant stakeholders, we identified the following 6 use cases (UC) to address the problems and provide the technical support to solve them by creating specific methods and tools:

- **Use case 1: Pre-planning of shared mobility services (Milan and Leuven)**
  This use case focuses on the optimal fleet size of shared mobility services (e.g. shared bikes, e-scooters) considering different parameters and constraints such as socioeconomic parameters, mobility, financial, and service provision-related. The urgent need is the designing of a tool which will be capable of providing solution to an optimization problem to minimise the generalised cost of trips as well as the cost of the system (including operating costs).
- **Use case 2: Operative areas analysis (Milan)**
  This use case targets at the allocation of existing shared mobility services' supply (i.e. operable fleet) to specific sub-areas of a metropolitan area with the aim of minimising economic losses of service providers and ensuring an acceptable level of service for citizens, in line with the principles of equitable transport systems.
- **Use case 3: Air quality and vehicle emissions analysis based on multi-source data (Barcelona and Leuven)**
  This use case supports the linkage and correlation of multi-source data including traffic-related, emissions-related, and weather-related data. The ultimate purpose of this linkage/correlation is to assess the impact of traffic on air-quality, forecast air quality in a short- to medium-term basis (e.g., 10 days), and/or simulate scenarios for the development and enforcement of air quality-related policies and policy instruments.

- **Use case 4: Planning for parking (Leuven)**
  This use case focuses on the assessment of traffic-related impacts of reducing on-street parking space within inner cities, thus supporting the formulation and enforcement of relevant policies and policy instruments, including excess searching time of affected drivers and the pressure relocated to areas adjacent to the affected one.
- **Use case 5: Inflows and outflows in a metropolitan area (Barcelona)**
  This use case revolves around the estimation of inflows and outflows between the districts of a metropolitan area based on data generated by point-to-point detection systems (i.e. Automated Number Plate Recognition systems) as well as of census data (i.e. vehicle registration). The ultimate purpose is to support the refinement and proper enforcement of environmental policies and policy instruments (e.g. low emission zones).
- **Use case 6: Assessment of traffic management scenarios (Thessaloniki and Leuven)**
  This use case involves the assessment of traffic management scenarios. The certain tool supports the assessment of C-ITS enabled traffic management scenarios based on simulation-based tools and data analytics, making use of multi-source data including data from connected vehicles fused with data from conventional counting systems.

All these use cases were implemented in the toolkit, some fully, others partially, thus providing researchers, planners, and policy makers with visualisations of the results derived from the methods and tools used in the case studies. The toolkit now supports answering the following questions:

- **Milan**:
  - How many shared (micro)mobility services need to be provided, and where?
- **Barcelona**:
  - How large are the vehicle emissions (CO_2, NO_x, and PM)?
  - How much vehicles drive from A to B?
- **Leuven**:
  - What is the impact of removing on-street parking spaces?
- **Thessaloniki**:
  - What is the impact of traffic management measures (traffic lights and speed limits)?

Creating the toolkit's back-end and front-end software

Integrating our the disruptive solutions and technologies from our use cases into coherent planning, decision making, and policy making for mobility is a huge challenge at current. The nuMIDAS project created a tangible and readily available toolkit to support local governments and bridge this gap by providing a comprehensive approach regarding what datasets, methodologies, tools, and models are required and which existing ones can be adapted. Moreover, nuMIDAS made policy decisions measurable and quantifiable, and impact assessments more tangible and directly usable. By applying research and implementing the tools in pilot cities with varying problems and characteristics, a wider applicability across Europe was guaranteed.

nuMIDAS's prototype development (i.e. its 'toolkit') approach was validated through an iterative approach within the six case studies in the different European pilot cities. We deploy the toolkit in each of those cities. Advanced methods and tools are required to analyse, assess, and monitor these new mobility solutions and policies including new data management techniques. The toolkit (in the form of a dashboard) incorporated these methods and tools providing researchers, planners, and policy makers a visualisation of the results through a GUI.

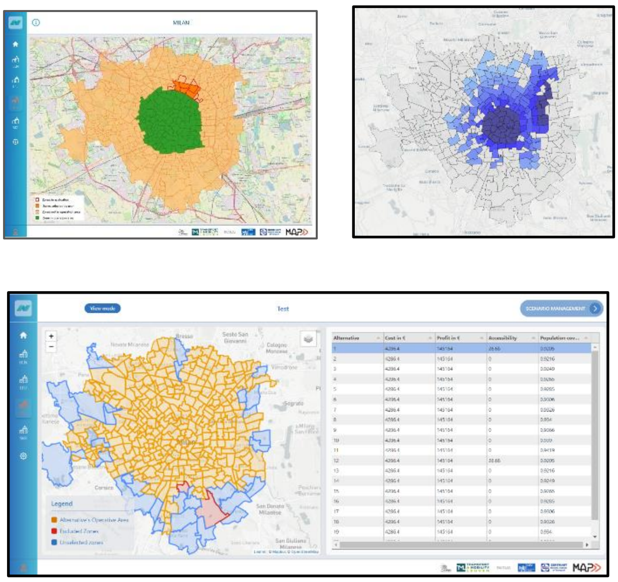
For each of the use cases, we devised new algorithms that took the current state of the art into account and add new elements to it. The algorithms were initially coded in Python and first tested under stand-alone lab conditions. Then they were ported to a back-end engine (forming part of the toolkit) that runs an instance of Amazon Web Services (AWS) with appropriate GIS-databases and input/output file handling capabilities. To perform smooth operations, the entire endeavour operates using private and public APIs, with the front-end system containing access control regulations and the visual part of the different use cases (e.g., graphs for geographical interpretations, monitoring of key performance indicators, etc.), as well as scenario management where suitable.

Example implementation of a use case: shared mobility planning

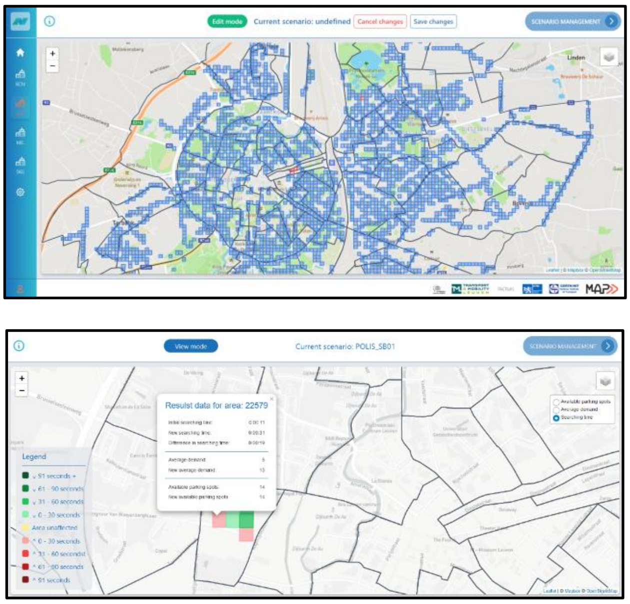
As an example, in the city of Milan, the policy maker required a tool for the preplanning of shared mobility services. The nuMIDAS team designed and developed a tool that processes available data to produce the output required by Milan city mobility planners. The aim was to produce a tool replicable and scalable in different cities/regions in Europe. In the case of station-based car-sharing, as an example, the dashboard suggests the proper location of new car-sharing stations and a well-balanced car fleet. This outcome is produced by back-end algorithms that elaborate data provided by the municipality. New car-sharing services, or extensions of the existing ones, can then be planned based on the outcomes of the nuMIDAS tool. The dashboard allows tuning parameters of the algorithms to compare different scenarios, depending on the weight given to conflicting objectives. Examples of the latter are the increase of shared mobility options to citizens in low-demand areas, and the economic sustainability of car-sharing operators. A policy maker can use the dashboard to link data sources and input parameters, and to visualise the results of the computation in a user-friendly environment, as shown in Figure 5 (top left). This specific example was tested in the case of Milan, but can be extended to be used by any European city willing to make use of a tool that supports car-sharing planning.

Example implementation of a use case: planning for parking

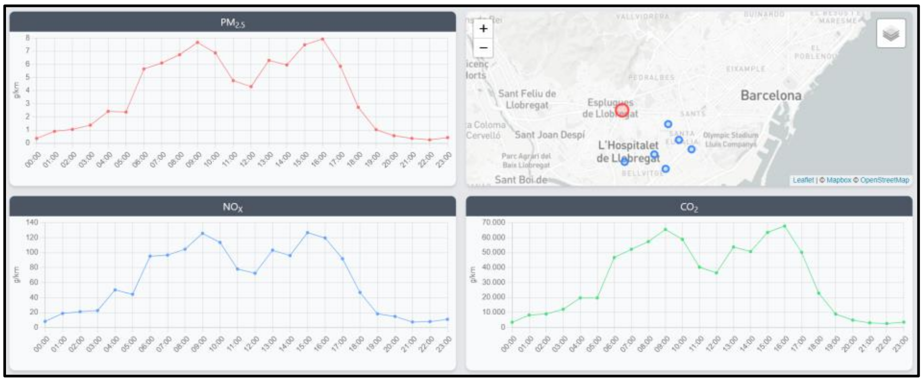
The main objective was to assess the potential impact of on-street parking restriction policies in the city of Leuven. The city is especially concerned with possible spill-over effects of hyperlocal policy changes, such as substantively reducing the available parking spaces in one street or neighbourhood. Through the simulation of enforcing a parking restriction policy in one or more roads of the network, both the policy maker as well as the transport planner are able to evaluate the effects, on the basis of the KPIs provided by the tool. Specifically, the evaluation of an on-street parking restriction policy includes the calculation of parking pressure, the calculation of searching time, and the examination of the extent of the effect, as shown in Figure 5 (top right).



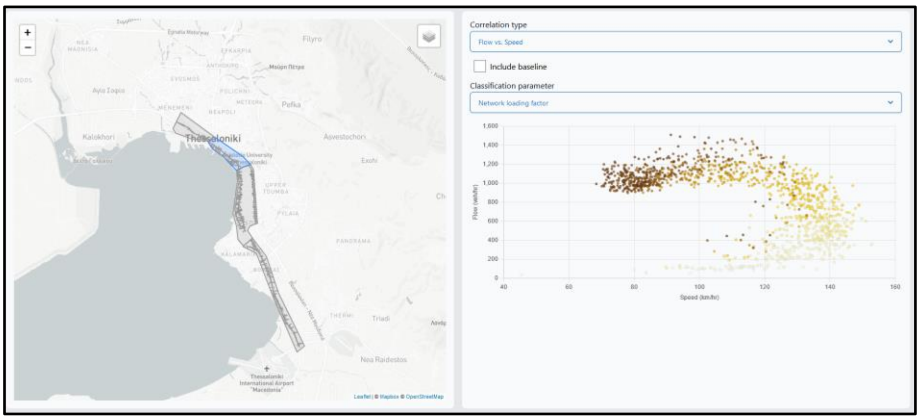
Use case: shared mobility planning



Use case: planning for parking



Use case: Air quality and vehicle emissions analysis



Use case: Air quality and vehicle emissions analysis

Figure 5 – Examples several use cases in the nuMIDAS toolkit's online dashboard.

Upscaling and transferability to other cities

In order to maximise the exploitation of project results, and in particular a widespread use of our new mobility toolkit, we drew up transferability guidelines. These describe how new cities can implement new instances of the tools within the nuMIDAS architecture framework, and use them for new mobility solutions analysis, assessing, and monitoring.

From an operational point of view, due to the city-specific and location specific parameters and constraints (air quality, origin-destination matrix, etc.), the guidelines transferred not the models themselves, but rather provided a useful methodology to adapt the model to each city.

Developing suitable business models

The state-of-the-art analysis provided early on in our project the basis for the work on business models for particular services. As the mobility field is rapidly changing due to, among others, digitalisation, as well as the uprise of small and large electric vehicles, business models and stakeholder roles change. Furthermore, more and more services combine many disciplines, which often means that services require multiple types of stakeholders to become effective. For this reason, a stakeholder analysis was performed in the context of nuMIDAS, in combination with a business model analysis.

The analysis was performed using a Service Dominant Business Model Radar (SDBM/R). The SDBM/R gives insight into which stakeholders can be found within the business model, as well as the way these stakeholders add value to this service. In addition to the SDBM/R, the analysis contains descriptions of the change in business models and stakeholder roles within the business models over time.

All SDBM/Rs were created per service, based on the achievement of shared goals and value co-creation by a group of actors (businesses, firms, and costumers) which interact to achieve that shared goal. This activity required to identify the values-in-use as the focal points of the services, and further the value propositions (part of the central values contributed by the particular actors), coproduction activities (i.e. those that actors perform to achieve the co-creation of the values), and costs and benefits for particular actors. The radars were complemented with the description of the corresponding business model scenarios, descriptions of actors and their roles and activities, and the discussions of the transitions of business models influenced by new methods and tools.

The summary resulted in a short list of the most common stakeholders within the SDBM/Rs. These are: municipalities, travellers, (mobility) service providers, intermediaries, and MaaS providers. The first three stakeholders within this list are most important and most common. These three stakeholders respectively provide policies, demand, and supply for transportation. The last two of these stakeholder types, intermediaries and MaaS providers, are not yet so common in the actual urban mobility field. These are categorised as future partners and are expected to become more prevalent. As transport systems become more and more integrated, while mobility service providers are competing, intermediaries stay independent and are able to handle data of competing partners with care to provide services which would otherwise not have been possible due to said competition. When the apps of MaaS providers finally really take-off, many services are expected to change, as mobility will be even more accessible from within our pockets. As such, our nuMIDAS toolkit is excellently positioned in light of further commercial exploitation.

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See https://numidas.eu/index.php/project-deliverables/ for a complete set of deliverables that were used as references, in particular:

- **Deliverable 3.4**: Final report on the formulation, evaluation, and prototyping of the advanced methods and tools
- **Deliverable 4.1**: Overview of traffic operations use cases
- **Deliverable 4.2**: Overview of emissions and air quality use cases
- **Deliverable 4.3**: Overview of dynamic mobility operations use cases
- **Deliverable 5.3**: Dashboard
- **Deliverable 5.4**: Transferability guidelines