nuMIDAS

Deliverable 2.2

Use cases definition – UML model

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Acronyms

EC	European Commission
EU	European Union
GA	Grant agreement
nuMIDAS	New Mobility Data and Solutions Toolkit
WP	Work package
D	Deliverable of the project (e.g. D2.1 is the first deliverable of WP2)
API	Application Programming Interface
DSS	Decision Support System
MaaS	Mobility as a Service
KPI	Key Performance Indicator
AI	Artificial Intelligence
ANPR	Automated Number Plate Recognition
C-ITS	Cooperative Intelligent Transport Systems
CAV	Connected and Automated Vehicles
ITS	Intelligent Transport Systems
UML	Unified Modelling Language
NTK	nuMIDAS Toolkit
UI	User Interface
UC	Use Case

1 Executive summary

Nowadays, the mobility ecosystem has drastically changed its shape through the rise of new stakeholders and services, including the gradual penetration of connected and automated vehicle technologies, mobility schemes relying on the principles of sharing economy. Although there are already many research and methodologies upon which many tools have been developed for supporting mobility planners and policy makers, there are still needs, which are differentiated in many thematic categories (e.g. transport planning, dynamic traffic monitoring), that require further research and development of additional tools to meet the current needs of the cities. As such, the current document focuses on the needs of the involved cities and on the requirements which the development and the use of the corresponding tools will be based on.

Therefore, the scope of this document is to identify the use cases that are of relevance for the project and its toolkit and provide both a high-level and detailed description of them, accompanied by specific needs and requirements. The final outcome is a consolidated UML model for the nuMIDAS toolkit.

Within the current deliverable the basic concept of use cases is extensively described. A holistic approach of use cases, the main scope of them and the importance of their existence before the development of a system/tool are presented and analysed. Specifically, an overview of the fundamental elements of use cases and the foremost benefits of their use are presented, combined with explanatory tables and figures.

The current deliverable also contains a detailed description of the methodologies upon which the scope of the use cases has been built. As it is described within the document, the main approach of collecting information and insights with the aim of defining the use cases in later stage, has its focus on the needs of the pilot cities themselves. In this respect, the pilot cities were requested to provide feedback regarding mobility-related problems that they are dealing with by responding to a questionnaire oriented to gather the functionalities that the nuMIDAS toolkit should entail and the availability of data supporting its operation. This survey is executed in cooperation with WP3 for the needs of D3.1. In addition, the outputs of D2.1 (Pribyl et al., 2021) concerning the state of the art and business modelling analysis, were used as input to the use cases scoping. Furthermore, with the aim of gaining a more concrete insight into the methodology of use case analysis to be adopted, a separate chapter is included in this document. Two types of strategies are followed one of which is the natural language and the other the visual representation based on UML. On top of that, the principles upon which use case analysis will be based are presented. These principles focus, in brief, on the: a) extensibility, b) interoperability, c) minimization of development and operational costs, d) reliability and e) usefulness and user-friendliness of the toolkit. By that, means emphasis is given on the harmonization of the development of the upcoming tools to successfully support transportation planners, researchers, and policy makers.

Subsequently, the document encloses the high-level description of the identified use cases. At first, it is described the problem to be addressed in the specific city(ies) and next the technical approach to be adopted. Specifically, the discussed use cases are the following:

1. Pre-planning of shared mobility services
2. Operative areas analysis
3. Air quality and vehicle emissions analysis based on multi-source data
4. Planning for parking
5. Inflows and outflows in a metropolitan area
6. Assessment of traffic management scenarios.

The UC1 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).

The UC2 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.

Next, UC3 focus on air quality and vehicle emissions analysis based on multi-source data. This tool 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.

The UC4is planning for parking. This tool 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.

The UC5 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).

The UC6involves 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.

Next, UML mock-ups provided giving the visual representation of each use case approach. UML mock-ups capture the entire process of a tool in combination with the interrelations with the involved actors. They set the boundaries of the tool and the steps to be followed each time. The resulting requirements are presented afterwards. Finally, the deliverable contains a consolidated UML model which describes all use cases in one figure. Along these lines, the scope of each use case becomes understandable and tangible.

To conclude this document summarises its achievements and makes mention of the future steps. This deliverable is deemed critical for the development of the upcoming tools, and it can be proved very useful material to guide the continuity and consistency of the nuMIDAS project.

2 Introduction

2.1 About nuMIDAS

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 it 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 & Solutions Toolkit, bridges this (knowledge) gap, by providing insights into what methodological tools, databases, and models are required, and how existing ones need to be adapted or augmented with new data. To this end, it starts 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 is guaranteed as all the research is 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 creates a tangible and readily available 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.

nuMIDAS, the New Mobility Data and Solutions Toolkit, started at the beginning of 2021 under the Horizon 2020 programme and it is being developed by a European Consortium, composed of 9 partners from 6 countries: Belgium, Czech Republic, Greece, Italy, The Netherlands, and Spain.

The project builds on a distributed selection of case studies in pilot cities to provide a geographic coverage of the EU. The three pilot cities are: Barcelona (Spain), Milan (Italy), and Leuven (Belgium). Thessaloniki has been also added to the pilot cities with the aim of adding to the scope of the project a use case involving traffic management and the use of cooperative technologies.

2.2 Purpose of this document

The current deliverable is associated with Task 2.3 and focuses on the high-level design of the nuMIDAS toolkit. This is done by setting the scope of the toolkit's use cases by utilising an agile approach building upon discussion with and questionnaires sent to pilot cities and the results of surveys, state-of-the-art and business modelling analysis executed in D2.1 (Pribyl et al., 2021). The resulting use cases are firstly justified and analysed in theoretical level and subsequently in a structured manner by adopting a methodological approach relying on the use of natural and unified modelling language (UML). The ultimate purpose of this document is to present the requirements for the project's toolkit derived from the analysis of all use cases oriented to provide solutions to problems and needs existing within the pilot cities. These requirements along with the foreseen workflow of each tool associated with each use case are then consolidated in a comprehensive UML model.

This document is of particular importance for and relates to the work planned to be carried out in the context of WP3, WP4, and WP5. Specifically, the identified requirements navigate the development of the methods and tools that will constitute the back end of the nuMIDAS toolkit. Furthermore, the derived methods and tools will be utilised, operationalised, and tested in the context of the case studies to be executed in WP4 and will be consolidated in the form of a dashboard (front-end) to be developed in the context of WP5.

2.3 Structure of this document

Apart from the included introduction and the main scope of the document, this deliverable consists of five additional chapters the content of which is described below.

Chapter 3 of this deliverable provides an overview on the concept of use cases, their main elements, and the resulting benefits. On top of that, the three main approaches for analysing use cases in the relevant literature and software/system engineering practise are presented and discussed.

Chapter 4 of the current document sets the methodology upon which the scope of the use cases of the nuMIDAS toolkit is defined as well as the methodology upon which the identified use cases are analysed with the aim of concluding to the requirements for the toolkit mentioned above.

Chapter 5 includes the description and analysis of the identified use cases. Specifically, its first part focuses on the description of the problem that each use case is called to address. This description is supplemented by a high-level overview of the scope and goals of each use case and the analysis of the reasons that have incited its analysis. Next, the second part includes a detailed technical description of use case by adopting a formal approach. In the third part, a UML representation is provided for each use case based on the evidence derived from the second part. The content of these three first parts are utilised as an input for the identification of the requirements for the nuMIDAS toolkit. The resulting requirements are presented in the last part of this chapter.

Chapter 6 consolidates the entirety of the outcomes of the analyses included in the previous chapter through the provision of a unified UML model. This model links the identified requirements, involved actors, and the process of each use case. Finally, conclusions and future steps are presented in Chapter 7.

3 Use case design basics

3.1 The concept of use cases

One of the main objectives of system design is to lay the ground for the development of a toolkit that will be based on a comprehensive and user-friendly architecture and structure. The first step towards this direction is the identification of system components in a simple, easy to read, and fully understandable manner. Many efforts and approaches have been made/suggested so far to conclude a good methodology for capturing the system functionalities and initial system's requirements.

One very strong-formulated technique is the so-called use case design. Use cases constitute a well written description of how a person who is involved in the system could accomplish its goal by following a specific process. In other words, a use case is the interrelation between the user and the system focusing on the prerequisite steps that a system must follow so that the user achieves the final desired result (Leffingwell & Widrig, 1999). Additionally, according to Booch et al. (1999), a use case is a description of a sequence of actions, including variants, that a system performs to yield an observable result to an actor. To such an extent, it is worth mentioning the fundamental elements that each use case should contain (Brian et al., 2009):

- Actors/users
- System
- Scenarios and their goals.

Users, who are involved with the system, are also knows as actors. Actors can be single persons, a group of people, another system or external inputs interacting with both the system and the whole process of a use case. Otherwise, whoever has an interest to system's behavior and may react to the process can be an actor (Kettenis, 2007). In most of the cases the difference between a user and actor is barely noticeable. The former is usually someone/something that utilises the system, whereas the latter is an entity assigned with using rights or an entity which is represented by a specific user (Papajorgji & Pardalos, 2006). A prominent example constitutes the nomination of a person included in the human resources of a specific entity (e.g. a public or private body) as responsible for using a system. Use cases are usually written from the user/actor's perspective.

The next fundamental element is the system itself. The system is the process that is required in order for the user to reach his/her final goal. As it is perceived, a goal or outcome is the desired result that an actor is trying to reach by interacting with the system. In some cases, the system may produce one outcome or in other cases multiple outcomes (Cacoo, 2018).

The ability of a system to produce multiple outcomes and adapt accordingly its functionalities is often achieved by including use case variations in the design process. These use case variations often termed as “scenarios” (Crystal Library, n.d.) consist of their own steps and conditions and are associated with specific goals that a user aims to reach. However, sometimes there is a need to extend the original or rigid goal(s) associated to a use case additional with soft goals that bring us to the concept of use case extensions or extension scenarios[1]. Use case extensions or extension scenarios are often utilised as a means of transfusing flexibility in a system during the design process, i.e. render the system capable of addressing exceptions, limitations, or specific circumstances. In such cases, the basic scenario is termed as “sunny day scenario”, reflecting the basic route that a system follows to cover the basic actor’s needs. On the other end of the spectrum, extension scenarios are termed as “rainy-day scenarios”, ensuring the operability of the system, when the actor needs to follow an alternative route with the aim of achieving an additional goal (Rosenberg & Stephens, 2007). The relationship between both an original use case/scenario and its extensions is depicted in Figure 1.

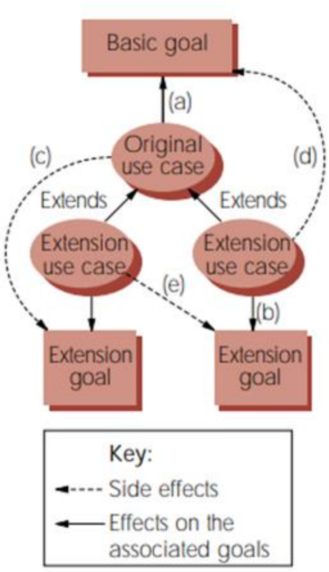


Figure 1: Relationship between an original use case and its extensions during system design (Source: Lee & Xue, 1999).

Additional, and contextually more complex, elements that are incorporated and present in use case design are the following:

- Events
- Stakeholders
- Preconditions
- Postconditions.

[1] Rigid goals are goals that shall be completely satisfied (thus corresponding to the basic scenario of a use case), while soft goals refer to desired properties of a system/tool (thus corresponding to extension scenarios).

Events are whatever trigger the beginning of a use case. Each use case normally has a main scenario to follow but sometimes, as mentioned above, there are also alternative scenarios. Different external events may trigger specific scenarios of a use case.

Stakeholders are intended as someone or something that cares about the progress of a tool system and is interested in its final outcomes. Stakeholders may, may not, or may to some extent interact with the tool (Study Academy, n.d.).

Furthermore, preconditions are those conditions or steps that are essential before initiating the use case. On the other hand, postconditions can be divided into success conditions and failure conditions. The former refers to all those actions, which successfully terminate the scenario, while the latter reflects the actions that unsuccessfully bring the scenario to an end (Crystal Library, n.d.).

Overall, use case modelling is a very useful and concrete technique to depict and illustrate the entire process to be followed for the development of a tool. By designing in a rigorous and explicit manner the use cases of a tool, many benefits may arise.

Firstly, once the use cases are explicitly and elaborately designed, the manner and order of the tasks and activities to be carried out by the tool becomes readily observable. Furthermore, the process of identifying and presenting user needs and requirements get easier and more readily understandable by any stakeholder. As it has been already mentioned, any person or other (external) system can contribute to the final outcome of the tool. In this respect, the documentation of such intervention(s) facilitates transparency and understandability of the outcomes of the tool on behalf of all stakeholders (Leffingwell & Widrig, 1999).

Moreover, use cases definitions clarify the initial structure and contents of a tool, thus preventing scope creep during the development of the tool. Scope creep describes a situation in which the development of a tool follows a repetitive and endless process without performance and progress that is attributed to a lack of strict definition and evaluation of the tool’s boundaries and target outcomes (Elenburg, 2005). On top of that, use case design facilitates the steps to be taken to develop a toll, thus enabling the definition of the development’s timeline (including performance monitoring). In this respect, by having identified the target outcomes resulting from each scenario but also the development timeline the feasibility of the tool to be developed can be verified (Aurum & Wohlin, 2005). To conclude, another noteworthy benefit is that use cases not only provide information concerning the steps to be executed by the tool, but also, they describe all the critical points that might go wrong. Hence, having an upfront overview on potential pitfalls during tool development enables the definition of mitigation strategies and resources saving afterwards.

3.2 Tools for use case design

There are many forms and tools for the representation and analysis of use cases providing varying level of depth/detail and formality. These forms and tools can be broadly discerned into a) natural language usage, b) visual models, and c) formal methods. The entirety of the aforementioned approaches can lead to satisfactory outcomes; however, the selection of the one to be followed depends on the needs of the users, the peculiarities of the tool and the variety of actors involved.

The first approach, which is the usage of natural language, is the simplest but not always the best way to describe the requirements of the tool. This approach is typically implemented through text documents with brief or long descriptions of the dependencies and interrelations between the actors and the behaviour of the tool. The usage of natural language for use case analysis is often termed as "user stories" the aim of which is to describe in a few sentences the content of the users' needs. It is worth mentioning that this technique does not go into detail. While, on the one hand, it is quite easy to use simple templates and frameworks to set the workflow of the tool without excessive effort to visualise and describe the use cases, this technique may not always lead to a concise definition of the tool's workflow and requirements. This is especially the case for tools enclosing an increased level of technical complexity. Further, when the system interacts with many actors, the number of use cases and by extension, the tool's goals are rapidly growing. This may imply an increased burden in terms of document management that may disturb the entire progress of tool development. Indeed, any change requests may require considerable manual effort associated, inter alia, with the time-consuming process of keeping all documents synchronised and up to date. For all those reasons, the adoption of a mixed technique for use case analysis and design, combining the use of natural language and predefined nomenclatures in the form of a table, can be considered preferable (Brian et al., 2009). The description of such a technique is provided in the ensuing paragraphs.

The next technique to be described focuses on how the designers convert the use cases from the level of understanding to the level of designing and implementation (Leffingwell & Widrig, 1999). This technique is based on the use of Unified Modelling Language (UML), involving the drafting of many types of diagrams (described later on), and has become the common practice in system design the last decades. UMLs are well suited to determining both the behavioural functionalities of a tool itself and the interactions of the tool with its external environment. In addition, UMLs may help all those software developers who are not conversant with all facets of the tool to comprehend faster its abstraction and functionalities. There are two categories of UML diagrams, namely the structural and behavioural. The former, concentrate on the more static elements of a tool, such as the objects and the intermediate links, while the latter focus on the most dynamic aspect of a tool like the interrelations between the objects and the corresponding goals, which must be accomplished (Dzidek et al., 2008). Figures 2 demonstrates both structural and behavioural UML diagrams.

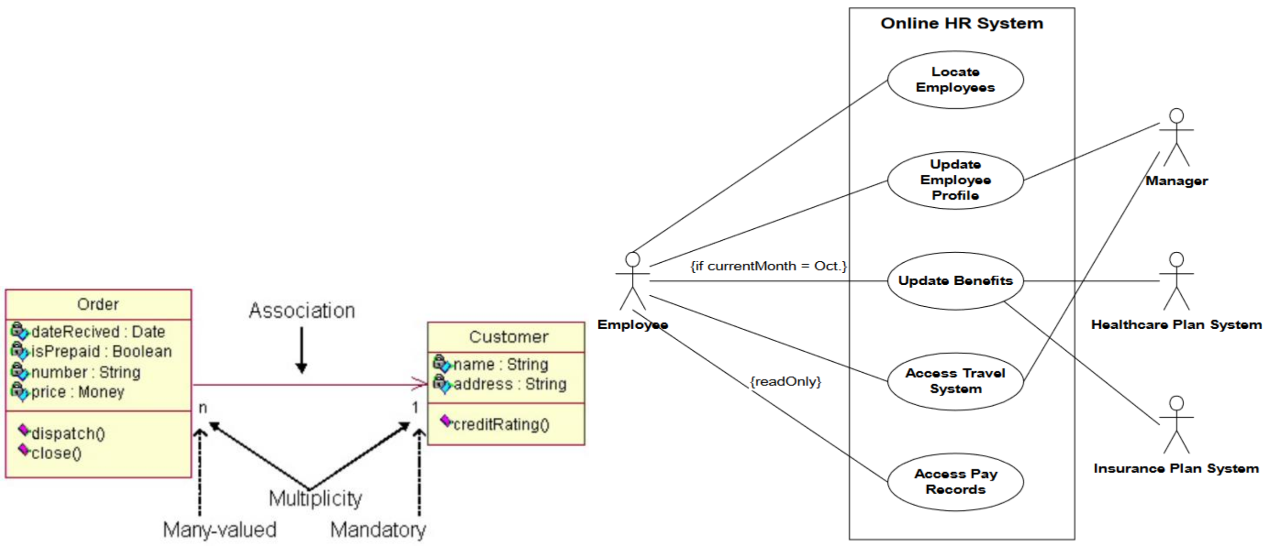


Figure 2: Example structural (left) and behavioural (right) UML diagrams (Source: Kobryn, 2000; Lo, 2014).

Another class of UML diagrams that fall into the behavioural category constitute the so-called activity diagrams. The main focus of activity diagrams is to describe the workflow of a system, including its computational and organization processes, step by step by capturing each of its dynamic facets (Tutorialpoints, n.d.; SparxSystems, n.d.). The difference between the conventional behavioural diagrams analysed above and the activity diagrams is that the former aim to showcase the functionalities of a tool, while the latter also encapsulate the flow and the connectivity among activities, the potential constrains, as well as the manner in which the activities are executed (GeeksforGeeks, 2018). In board lines, activity diagrams can illustrate the process followed by a combined with all tool's requirements and constraints and concurrently give emphasis on the sequence and conditions of the flow. The basic structure of an activity diagram is illustrated in Figure 3.

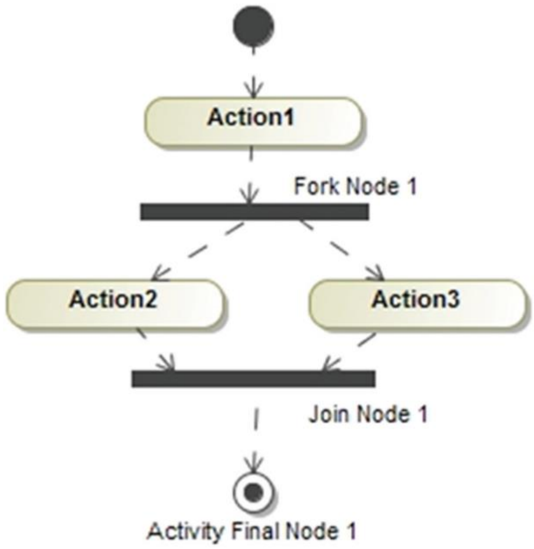


Figure 3: Structure of an activity diagram (Source: Huang et al., 2020)

The last technique for representing the functionalities and requirements of a tool along with their goal is the formal method, accompanied by tables and strict templates. Their purpose is to clearly define what the software tool must do to provide value to the end user. This method is a synthesis of the previous two since it utilises the structure of visual representations included in UML diagrams and the natural language to describe a tool's facet. It follows a strict and precise structure with certain criteria and aims to depict all the necessary acts that a tool should do in order to finally achieve the users' goal under different circumstances. Figure 4 indicates the elements of formal use case description template.

Use Case Name		[Name of the use case]
Actors		[An actor is a person or other entity external to the system being specified who interacts with the system and performs use cases to accomplish tasks]
Preconditions		[Activities that must take place, or any conditions that must be true, before the use case can be started]
Normal Flow	Description	[User actions and system responses that will take place during execution of the use case under normal, expected conditions.]
	Postconditions	[State of the system at the conclusion of the use case execution with a normal flow (nominal)]
Alternative flows and exceptions		[Major alternative flows or exceptions that may occur in the flow of event]
Non functional requirements		[All non-functional requirement: e.g., dependability (safety, reliability, etc.), performance, ergonomic]

Figure 4: Structure of a formal use case description template (Source: Guiochet, 2016).

Overall, a use case model may consist of both diagrams and textual description in order to be addressed as comprehensive and useful for tool developers. Indeed, having designed a UML without any textual description, there is a lack of information that may provide clarifications on the tool structure and specific functionalities. To the contrary, the absence of any visual representation complicates the understandability of the interaction of an actor/stakeholder with the tool (Elenburg, 2005).

4 nuMIDAS approach to use case analysis

4.1 Methodology for use case scoping

The first step for the design of the nuMIDAS set of methods and tools (hereafter referred to as the nuMIDAS toolkit) is the identification of the scope of the use cases to be addressed. This scoping exercise follows an agile approach consisted of two iterations (Figure 5).

Figure 5: Adopted approach for nuMIDAS use case scoping.

The first iteration includes the initial definition of the use cases scope taking as input the outcomes of:

- a close cooperation and discussion among the project’s partners, including representatives of the project’s pilot cities (Milan, Leuven, Barcelona, Thessaloniki), focused on the problems faced by these cities;
- a questionnaire sent to these cities partly oriented to gather input concerning the desired purpose and functionalities of the nuMIDAS toolkit, the shortcomings of any currently utilised methods or processes, as well as data availability in these cities[2];
- the state-of-the-art and business modelling analysis being the focus of D2.1 (Pribyl et al., 2021);
- the outcomes of a survey targeting key stakeholders and experts (executed in the context of D2.1 (Pribyl et al.)), focusing on the identification of challenges and trends in the urban mobility ecosystem.

[2] The remaining part of the survey was oriented to provide input to the risk assessment executed in the context of D3.1.

Subsequently, the results of this iteration were handed over to second iteration in which the contents of the derived use cases have been once again discussed by all project's partners. The main goals of the second iteration are ensuring that the problems reported by the pilot cities are addressed, increase the innovativeness of the nuMIDAS toolkit, and ensure that trends and challenges identified for the urban mobility ecosystem are properly covered. This iteration also includes a preliminary assessment of the technical feasibility of the derived use cases, as well as the enrichment of the use cases description with critical parameters to be addressed by the nuMIDAS tool that have been identified in the context of D3.1.

The results of the scoping of the use cases of nuMIDAS toolkit are presented in Section 5.1 and also reflected in the description of each use in Section 5.2.

4.2 Adopted methodology for use case analysis

This section sets the methodology upon which the identified use cases will be analysed as well as the whole process to be followed until the identification of the requirements for the nuMIDAS toolkit.

Concerning the analysis of the identified use cases, it is deemed appropriate to combine existing methodologies and tools as those are mentioned in Section 3.2. This strategy is selected in an effort to take advantage of the merits of each methodology and mitigate potential deficiencies that may be the product of using a single methodology (e.g. the usage of natural language promotes creativity during the inception stage of the toolkit, while the usage of UML models promotes the in-depth understanding of the structure of the tool and its interaction with its users).

The adopted approach includes, at first, a detailed technical description of each use case using natural language, accompanied by the delineation of:

- the main functionalities of the toolkit resulting from each use case;
- the actors involved in each use case;
- the targeted users of each use case;
- the required input for each use case;
- the high-level computational process to be followed by the toolkit;
- the outputs provided to the users.

This approach for the detailed technical description of the toolkit's use cases closely resembles the principles of the so-called formal method described in Section 3.2. Specifically, the elements listed above form the structure of a table that is strictly filled in with the details of each use case. The visual representation of the computational process to be followed by the toolkit depict the necessary steps that will conclude to the achievement of the goal(s) set in the description of each use case. This representation constitutes the first attempt for investigating the manner based on which the input of a user will be transformed into outputs by the toolkit. In addition, the goal(s) set in the description of each use cases are visually represented, where needed, to facilitate understandability of the target outcome.

Subsequently, the results of this detailed description process feed the drafting of an intermediate representation for each use case complying with the principles of UML modeling (hereafter referred to as "UML mock-ups"). By that means, the technical details of each use case are included in a single image providing a quick snapshot and overview over the abstraction and functionalities of each tool as well as on the involvement of targeted users. For this purpose, it is deemed appropriate to adopt the behavioural approach of UML modelling, enabling the understanding of all incepted elements of the tools and their interrelation with the users and the goal(s) set.

As noted in the beginning of this section, the ultimate purpose of this deliverable is the identification of the requirements for the nuMIDAS toolkit. This purpose is served by adopting a participatory approach, involving all project partners. Specifically, all project partners were provided with the technical description and the UML mock-ups of each use case, and they were requested to identify and state which are the requirements that derive from each use case.

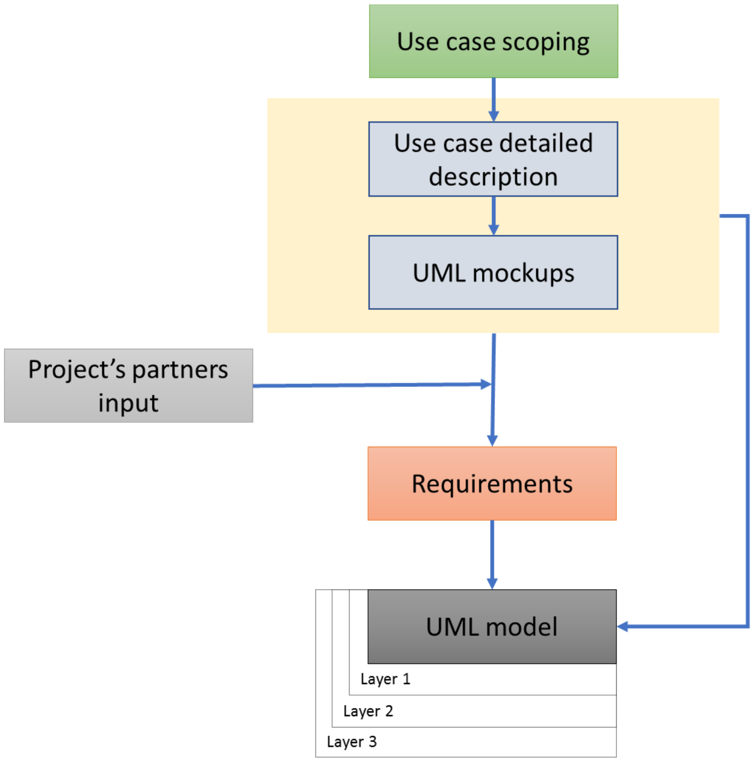


Figure 6: Methodology for use case design and analysis.

The final outcome of this deliverable is the provision of a comprehensive UML model, consolidating the entirety of the intermediate steps of nuMIDAS use case design. This model is comprised of the following three layers:

- **1st layer**: high-level overview of the toolkit content
- **2nd layer**: link of each use case with specific actors and identified requirements
- **3rd layer**: activity diagrams demonstrating in a precise manner the computational and data flow of the tools to be included in the nuMIDAS toolkit.

The adopted overall process for designing and analysing the use cases of the nuMIDAS toolkit is schematically depicted in Figure 6. It should be noted that according to the theory of use case design each use case is extended to satisfy additional needs, this is not done in the context of the current deliverable the objective of which is to conceptualise and provide an initial design for the nuMIDAS toolkit. However, use case extensions will be provided in the following deliverables of the project reflecting emerging needs and new insight from the development process. On top of that, use case extensions may be the product of the design of the toolkit's dashboard.

4.3 Design principles

The aim of nuMIDAS project is to deliver a set of tools and solutions for supporting the proper functioning and planning of urban mobility ecosystem considering new and emerging mobility trends, challenges, new concepts, important variables as well as making increased use of available and new mobility data. In this respect and having in mind the dynamic and evolving nature of the aforementioned ecosystem, the project team has decided to adopt a set of principles that will navigate the design of the project's toolkit through the adopted use cases. These principles are the following:

- **Extensibility:** It refers to the ability of a tool to be extended with a certain level of effort through the incorporation of new functionalities or the adjustment of the current ones in order to be capable of satisfying new needs, responding successfully to new challenges, and supporting additional use cases. This can be achieved by adopting upfront a modular architecture for the toolkit to be developed (Standish, 1975).
- **Interoperability:** It refers to the ability of a tool to cooperate and exchange information harmoniously with other tool without severe restrictions. This property should encompass the whole processes of the toolkit, including data ingestion, computations, and results reporting. This can be achieved by using the appropriate API-based endpoints and communication interfaces. Interoperability among tool s can be also achieved by identifying the parameters, the needs, and requirements of all tools to be involved, fostering, therefore, a high level of fidelity and accuracy (Ford et al., 2008).
- **Minimization of development and operational costs**: The minimization of development and operational costs of the nuMIDAS toolkit relies on the strict definition of its requirements by adopting a UML-based approach and the increased use of open-source solutions for achieving the desired goals. While the latter constitutes a topic to be addressed at a later stage of the project (e.g. in the context of WP3 and WP5), the former is addressed in the context of the current deliverable.
- **Reliability:** It refers to the quality of a tool to produce reliable results irrespective of whether provided input is case-specific or not. During the whole process of designing a tool, reliability parameter should be taken into account. For this reason, the use cases analysed in the current document have been scoped, among others, considering problems faced by European cities, but their analysis and elaboration is case agnostic (Van Oort & Van Nes, 2009).

- **Usefulness and user-friendliness (simplicity):** They refer to the quality of a tool to provide solution to existing problems through a user friendly and fully understandable manner. While the latter is a topic to be addressed mainly in the development of the toolkit's dashboard (WP5), the former is addressed in this deliverable by setting the scope of the toolkit use cases considering, among others, existing problems faced by European cities, literature findings, as well as trends and challenges mentioned by experts in urban mobility. Although simplicity seems obvious, it is a prominent technique to appropriately design a tool with fewer but at the same time more concrete properties and features. The simpler is a structure of a tool, the higher is the efficiency of the user (Resnick et al., 2005).

5 Analysis of nuMIDAS use cases

5.1 Scoping and justification

5.1.1 Use case 1: Pre-planning of shared mobility services

The emergence of new mobility modes, such as shared electric scooters (e-scooters) and either docked or dockless bicycles, grouped under the umbrella of micromobility, provide opportunities for alleviating several issues of (European) cities, including congestion and adverse environmental impacts of mobility (Dias et al., 2021). Mobility services enabled by these modes provide an appealing alternative to conventional public and private transport services but also to private cars. They are operated by a wide range of service providers around the globe, thus forming a new type of international industry. The operation of shared mobility services is typically regulated and monitored by the public sector, including local governments and municipalities, through service tenders. In this respect, a crucial question that comes into play concerns the specification of these tenders to enable the provision of services beneficial for the end-users as well as viable in the long run. Consequently, the local departments tasked with issuing these tenders shall factor in both the needs and attitudes of citizens as well as other parameters regulating the operational efficiency and financial viability of these services. A crucial parameter that affects both the level of service and the operational efficiency is the fleet size of such services. Indeed, a lower than needed fleet size will conclude to a poor level of service and negative impact on the level demand for shared mobility services. On the other hand, a higher than needed fleet size will provide an increased level of service but will dramatically decrease the operational efficiency from the service operator's perspective, thus impacting negatively on the operators earning and hampering the financial viability of provided services. Therefore, the UC1 of the nuMIDAS toolkit revolves around the development of a high-level DSS tool supporting the identification of the optimal fleet size of shared mobility services taking as input socioeconomic, mobility, financial, and service provision-related parameters and constraints. Such a tool should ideally account for demand fluctuation caused by unexpected events, such as the COVID-19 pandemics, seasonal fluctuations, which caused either an increase or decrease in the level of demand for certain transport modes (Fisher et al., 1994). It is expected that this tool will enable a preliminary planning of shared mobility services to be deployed within a specific area and the issuing of tenders including rational terms and conditions.

This use case has been conceptualised in cooperation with representatives from the city of Milan. Specifically, the city is interested in improving the process of issuing tenders for shared mobility services, given that they provide a fixed number for the required fleet, which creates complexity in the sense that the market can fluctuate, and demand can change over the time of operation. In addition, it is a concern of the city to ensure a sufficient level of service at an accessible price not only within the inner city of Milan but across the whole metropolitan area. This use case is also relevant for the city of Leuven, which is interested in improving the planning processes of shared mobility services. On top of that, policy instruments analysed in the context of D2.1 (Pribyl et al., 2021), such as Low Emission Zones, rely to a great extent on the availability of shared mobility services providing beneficial services to citizens within inner cities. Furthermore, one of the main challenges to be addressed by the Rental and Micromobility services analysed in the context of D2.1 (Pribyl et al., 2021) is the optimization of the operable fleet to meet successfully existing demand. Moreover, as suggested by Shaheen and Cohen (2019) and Nikitas (2019) there is a need to define proper fleet management policies, in the sense of rebalancing fleet to achieve a proper density and service equity. In this respect, both the optimization of the operable fleet and the enforcement of fleet management will prove ineffective if the size of the fleet is a priori not adequate. Apart from operational concerns and as noted in D2.1 (Pribyl et al., 2021) (Section 4.3.7.7), an excessive fleet size may lead to an excessive use of public space triggering the need for legislative regulation. The identification of the required fleet to be included in public tenders for car-sharing operators is also identified as a gap in D2.1 (Pribyl et al., 2021). Similarly, the obligation of the cities to set a minimum level of service or maximum fleet size constitutes a challenge of mobility management (Section C.4.4) and their main responsibility while orchestrating the scenery of provided micromobility services (Section D.7). Finally, based on the results of the survey executed in the context of D2.1 (Pribyl et al., 2021) targeting key stakeholders and experts of urban mobility and the identification of the most important challenges, it is derived that (environmental) sustainability constitutes a core challenge. The vision for sustainability can be achieved through the usage of policy instruments promoting the usage of transport modes relying on alternative fuels. Given that compatible technologies are heavily utilised by shared mobility operators, the provision of effective and viable relevant mobility services can used as an additional policy instrument.

5.1.2 Use case 2: Operative areas analysis

The vision of achieving sustainable mobility within European metropolitan areas has led to the wide recognition of the need to operate in these areas new environmentally friendly modes of transport and promote the usage of public transport services (Midgley, 2011). However, metropolitan areas in Europe and beyond are sprawled across large geographic areas, including both densely and less densely populated sub-areas. While the demand for public transport and shared mobility services in densely populated sub-areas is typically high, thus facilitating the cost-efficient deployment of a wide range of relevant services, this is not the case for less densely populated sub-areas. This fact often results in the existence within the same metropolitan area of overserved and underserved sub-areas in terms of offered mobility services, questioning the principles of equitable transport systems (Caggiani et al., 2019). Thus, a critical concern of cities and transport planning authorities is to identify which mobility service operators will be active in which sub-area and to what extent in order to cover not only the city centre but also the peripheric areas of the city. The UC2 of the nuMIDAS toolkit aims to support this need focusing on shared mobility services though the development of a DSS tool that will distribute existing supply, in the form of operative fleet size into specific high or low demand sub-areas of a wider metropolitan area. Such a distribution will seek to maximise the level of service within each sub-area, minimise the economic losses of service operators, and ensure equity among sub-areas in terms of level of service and among operators in terms of treatment (i.e. services operators should be treated equally).

This use case has been conceptualised in cooperation with representatives from the city of Milan. Specifically, these representatives have expressed the ascertainment of the city that there are more and less attractive areas in terms of the economic profit for operators but at the same time there is the need to define service areas that include peripherical zones of Milan. In this respect, the city needs a model for calculating the operative areas in which operators reach most of the Milan metropolitan region without incurring economic losses in low demand areas. Through this use case, an important challenge mentioned in the analysis of MaaS service in the context of D2.1 (Pribyl et al., 2021) will be examined and addressed. This challenge is the management of competition between service operators by supporting the equal distribution to them of attractive service areas. Moreover, this use case can be viewed as an extension of the UC1, in the sense that a proper spatial planning of mobility services provision will promote both the level of service provided to the end users and the financial viability of services. The latter is attributed to the facilitation of fleet management policies discussed in D2.1 (Pribyl et al., 2021). Finally, the implementation of this use case in metropolitan areas is expected to lead to an improvement of important new (social-related) KPIs that have been identified in the context of D2.1 (Pribyl et al., 2021), including accessibility to all, equity in mobility offer, inclusiveness, and decrease of the modal share of private vehicles (cars).

5.1.3 Use case 3: Air quality and vehicle emissions analysis based on multi-source data

Vehicle traffic is an important contributor to air pollution especially within urban areas. In most cases, this is the product of congestion and excessive vehicles' starts and stops at signalised intersections. On the other hand, promoted concepts, including sustainability, liveability, and quality of life, indicate that there is a clear need to reduce vehicle emissions within urban centres, thus alleviating adverse environmental impacts of traffic (Nešić et al., 2015). In line with this need, a wide range of policy measures has been suggested and applied in several European cities, such as low emission zones and speed limits' restrictions along with specific segments of the urban and peri-urban road network (Holman et al., 2015). In addition, the reduction of vehicles' emissions is one of the main goals of traffic management scenarios applied in several European cities. The main prerequisite for planning such policy measures and traffic management scenarios and assessing their success rate is the availability of a proper methods and tools for quantifying the effect of vehicle traffic on air quality based on multi-source data. The inputs required by relevant models typically include fuel specifications, statistics on fuel consumption, the types of vehicles included in the fleet taken into consideration during the analysis, average speed, as well as the annual mileage per vehicle or road class. The UC3 of nuMIDAS project includes the development of a framework, which analyses daily traffic intensity in relation to climatological, emission data, events, and other relevant sources of emissions. In addition, this use case will allow to forecast air quality in a mid-term basis (e.g. in the next 10 days) and simulate scenarios for the development of future vehicle private restriction measures.

The content of this use case has been identified in cooperation with the city of Barcelona. Specifically, it is within the interest of Barcelona to define daily traffic intensity profiles crossed with climatological data and emission data that may be further used to simulate scenarios, involving traffic and emissions prediction, taking as input vehicle restriction measures, meteorological forecasts, and planned events. This use case is expected to support policy makers in Barcelona towards better planning and assessing enforced policy instruments, such the Low Emission Zone, using multi-source data. Furthermore, this use case is of interest for the city of Leuven, which is interested on assessing the traffic impact on air quality, using citizens science data sources concerning traffic conditions and air quality. The scope of the UC3 and data availability in the cities mentioned above forms an application area of the Data Analysis service described in D2.1 (Pribyl et al., 2021), including the exploitation of AI-based algorithms (e.g. supervised learning algorithms).

5.1.4 Use case 4: Planning for parking

The massive usage of private vehicles within metropolitan areas constitutes an important part of the negative externalities of the transport sector, including increased road congestion, road accidents, environmental pollution, and noise level (Zhang, 2013). Such a situation is further exacerbated by vehicles circulating in search of a parking lot. In this respect and considering that parking is an important traffic generator, an effective measure for alleviating the above issues and reducing private vehicle attractiveness within metropolitan areas is the reduction of on-street parking space. Such a measure, including other parking management policies, has both positive and negative implications. Positive implications include the alleviation of road congestion due to the reduced, at least in the long run, attractiveness of private vehicles within urban centres and the reduced emissions, noise level, and road accidents due to reduced congestion. Parking space reduction free significant areas to be used for more social and environmentally friendly purposes such as increase urban vegetation, increase pedestrian areas, and bike lanes. On the other hand, negative implications include economic losses of businesses operating within the area in which a restrictive parking policy is enforced, parking shortages and parking pressure relocated to adjacent areas (in which less restrictions are in force), increases in searching time and egress time (including walking time), as well as the pressure applied to alternative transport modes, including required investments for increasing their capacity (due to a potential shift in mode choices in the long run). Another observation regarding these impacts is that they may be discerned into short-term and long-term. For instance, the alleviation of road congestion and the reduction of vehicle emissions constitute two positive impacts that are expected to be realised a significant time period after the enforcement of parking restriction policy.

The UC4 of nuMIDAS toolkit involves the development of a methodology for assessing the impacts of reducing on-street parking policies (or applying charging instruments), placing special emphasis on short-term traffic related impacts, such parking pressure relocation and increases in generalised transport costs. This methodology will rely on the analysis of data providing information on parking availability and the use of GIS-based tools.

The scope of this use case has been defined in cooperation with the city of Leuven, which is interested in visualising the impacts of reducing on-street parking and the exploitation of available parking management data. Furthermore, through this use case it is expected to support the assessment of the short-term adverse impact of mobility policies discussed in D2.1 (Pribyl et al., 2021) related to parking regulation (e.g. in Section 4.3.2.6 4.3.3.6, 4.3.5.6, and 4.3.3.6), the ultimate purpose of which is to mitigate car related externalities, reclaim public space, and reduce car ownership and car use. In addition, this use case will provide insight on the side effects of one of the tools of on-street parking management, analysed as a service in D2.1 (Pribyl et al., 2021). This use case is directly associated with two challenges identified by key stakeholders and experts in urban mobility (D2.1 (Pribyl et al., 2021)) relating to impact assessment and urban space management.

5.1.5 Use case 5: Inflows and outflows in a metropolitan area

Recent advancements in vehicle sensing and detection provide a wide range of opportunities for transport planning. A prominent example constitutes point-to-point detection systems relying on several technologies, such as Bluetooth detectors, Automated Number Plate Recognition (ANPR) cameras, GPS enabled probe vehicles (Floating Car Data), or personal devices. Enabled use cases include the estimation of origins and destinations of vehicles and travellers' trips as well as the travel times along specific paths or road segments (Mitsakis et al., 2015). The estimation of the origins and destinations of vehicle trips is of particular use for large metropolitan areas given that they inform transport planning authorities on the extent to which prevailing traffic conditions are a product of internal, inbound, outbound, or through-going vehicle trips. The UC5of nuMIDAS toolkit includes the development of a framework for estimating the inflows and outflows between the districts of a metropolitan area to assist the formulation and/or management of mobility policies oriented to control traffic and vehicle emissions. Such an estimation will be based on Automated Number Plate Recognition (ANPR) cameras installed at specific locations of a metropolitan area, including the borders between its various districts and cities in the metropolitan area. Challenges relating to data privacy should be addressed in this use case.

This use case has been conceptualised in cooperation with the city of Barcelona. Specifically, it is within the interests of the city to improve mobility planning processes and acquire a better knowledge about users and mobility patterns. A valuable aid towards this direction would be the definition of an Origin-Destination (OD) Metropolitan matrix using as data input the detections of the available Automated Number Plate Recognition (ANPR) systems. By that means, the city will be able to better understand the effectiveness of the Low Emission Zone enforced in the city (and any necessary adjustments) but also to plan public transport services, including, among others, park and ride facilities and services. In addition, the survey executed in the context of D2.1 (Pribyl et al., 2021), targeting key stakeholders and experts in urban mobility has concluded that the exploitation of ANPR data for the definition of environmental policies and the implementation of environmental zones in certain part of a metropolitan area constitutes a trend for the urban mobility sector (E.3.1). On top of that, respondents have indicated that traffic-related Big Data collected from cameras constitute a fundamental tool to be exploited by policy makers to support mobility-related analyses and policies.

5.1.6 Use case 6: Assessment of traffic management scenarios

The knowledge on the prevailing traffic conditions resulting from the increased connectivity between vehicles and the transport infrastructure or third-party systems provides several new opportunities towards the active management of traffic within urban areas. A crucial step before the development as well as during the operations of any active traffic management system constitutes the identification and assessment of traffic management scenarios, thus providing a link between the operational management of traffic and transport planning (Klein, 2018). Such an assessment may be either simulation-based or data-driven, enabled by the real-world application of a traffic management scenario and monitoring of its results. These scenarios may be based on a variety of means, such as the dynamic adjustment of traffic signal control plans, the use of C-ITS services (e.g. provision of warnings, information, and routing advice), provision of information and guidance through Variable Message Signs, as well as other techniques, such as ramp metering. The UC6 of nuMIDAS project aims to develop a robust methodology comprised by simulation-based tools and data analytics, for assessing C-ITS enabled traffic management scenarios, making use of multi-source data, including Connected Vehicle Data merged with data from conventional counting systems.

This use case has been conceptualised in cooperation with the city of Thessaloniki, which despite not initially included in the pilot cities of the project it has been added as such with aim of analysing the topic of traffic management, focusing on the data-driven assessment of traffic management scenarios. Specifically, within Thessaloniki several methods and tools are being developed and gradually deployed for utilising the capabilities offered by Cooperative Intelligent Transport Systems (C-ITS) and connected vehicle technologies in the active management of traffic. In this respect, it constitutes a valuable playground for testing data-driven traffic management scenarios' assessment techniques, the logic of which can be then adopted by other interested European cities. A prominent example constitutes the city of Leuven, which is interested in developing traffic management technologies. Besides, through this use case several gaps mentioned in the analysis of C-ITS and Connected and Automated Vehicle (CAV) technologies, executed in the context of D2.1 (Pribyl et al., 2021) (Section 4.3.10.4), are expected to be filled. These gaps include, but are not limited to, the lack of commonly accepted methods/tools to assess the potential impacts of traffic management scenarios in large-scale mixed vehicle fleet environments, the low utilization of data derived either from data consolidation platforms (e.g. the National Access Points operated by Member States) or connected vehicles to assess and implement traffic management scenarios, as well as the low connection of C-ITS with the operational management of traffic. Moreover, this use case will attempt to exploit the opportunity derived from the increased availability of multi-source data for supporting ITS applications (Section 4.3.10.5). Finally, through this use case a trend that has been identified as relevant for the upcoming 10 years by key stakeholders and experts in urban mobility (Section E.3.2) relating to smart roads and the adoption of KPI-driven traffic management approach (instead of the basic condition/action-based approach) will be fully addressed and analysed.

5.2 Technical description

This section builds upon the previous one by providing a technical description of each of the identified use case of the nuMIDAS toolkit. As outlined in Section 4.2, such a description is based on the adoption of a formal approach. Specifically, each use case is described in the form of a table whose content is shown in Table 1.

Table 1: Adopted approach for the technical description of nuMIDAS use cases.

Use case number: *The number of each use case following an ascending order.*
Use case title: *The title of each use case indicating its scope.*
Use case description: *A detailed description of the scope, assumptions, and goals of each use case.*
Functionalities: *A listing of the main functionalities of the nuMIDAS toolkit enabled by the analysis and incorporation of each use case.*
Actors involved: *Actors that may be involved in each use case.*
Users: *Targeted users in each case. These users can either provide input or received outputs from the tool.*
Data inputs/needs: *Required input for accomplish the process of each use case.*
Process: *A flowchart indicating the process flow included in each use case.*
Data outputs: *The outputs of the process flow included in each use case.*

Based on the approach shown in Table 1 and the scope and objectives of each use case discussed in Section 5.1, a technical description is provided per use case in Tables 2-7.

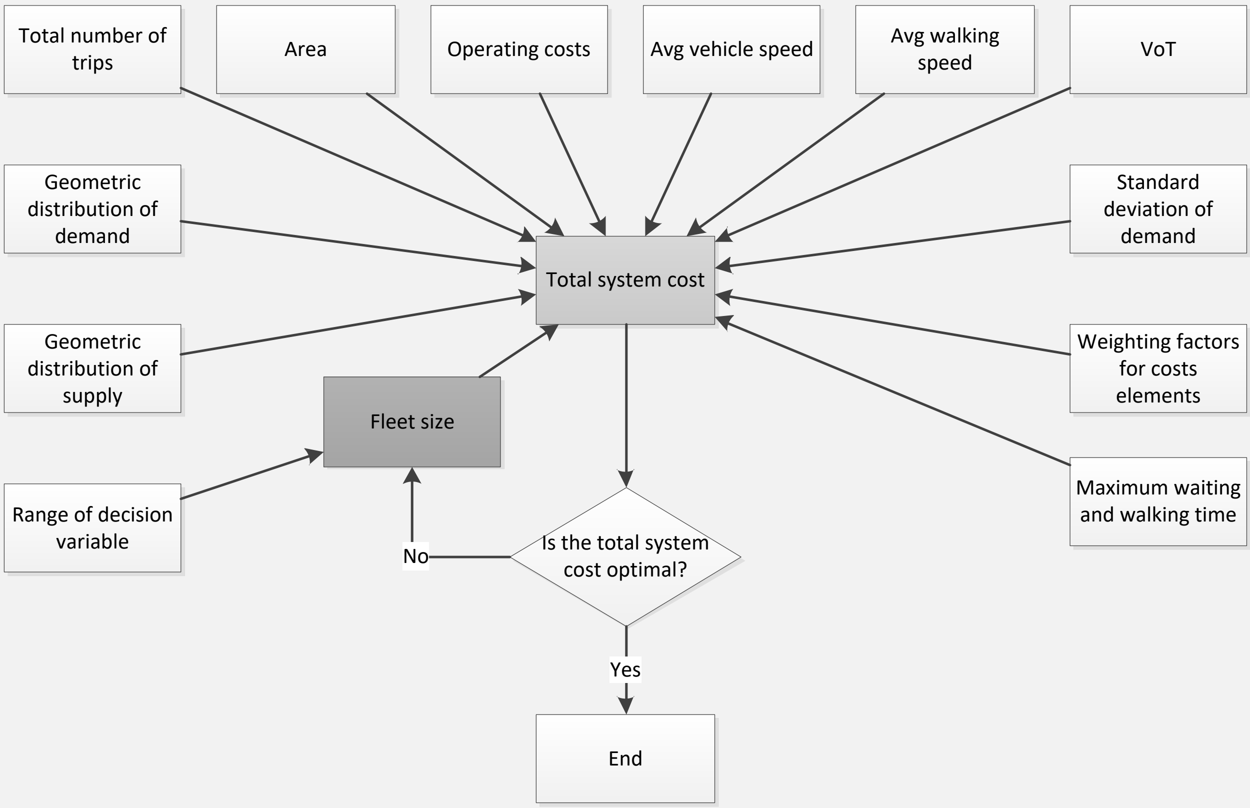
Table 2: Technical description of Use Case 1.

Use case number: 1
Use case title: Pre-planning of shared mobility services
Use case description: The scope of the first tool to be integrated in the nuMIDAS toolkit is to support policy makers to determine properly the fleet size of shared mobility services to be operated within a given area. In this respect, policy makers will be able to include rational terms and conditions during the preparation of relevant tenders for services within the area of their jurisdiction. Focus will be given on micromobility, such as bike-sharing or (e-/kick-) scooter-sharing, and car-sharing services. The fleet size will be determined considering both the perspective of service operators and the perspective of end users. According to the former, there is a need to identify a value for the fleet size that will lead to the maximization of revenues and the minimization of financial losses. According to the later, there is a need to identify a value that will lead to the minimization of the generalised cost of trips. By that means, the suggested value will enable the provision of beneficial services for service operators that will jointly comply with minimum level of service requirements, e.g. fleet size will not be extremely large to exceed the desired operational costs and concurrently the end users will be adequately served without having to wait for a long time or walk long distances. To this end, the tool will provide solution to an optimization problem, which will involve the minimization of an objective function reflecting the total cost of the system. This function will be multi-parametric to cover both perspectives mentioned above. The first term of this function will relate the time spent by users either to acquire access to these services or to reach their destination by using these services with the value of their time. The second term will involve the financial losses of service operators caused by the inability to serve a fraction of existing demand, while the remaining terms will involve the maintenance, operational, and capital costs induced by service operators. This optimization problem will also include constraints reflecting the maximum waiting and walking of end users. The parameters mentioned above will be either user-defined or approximated by the tool itself using geometric probability distributions. Having defined these parameters and constraints, the tool will execute iterative calculations to identify the optimal value for the fleet size. Based on the nature of the micromobility service under investigation (e.g. dockless vs. docked) the tool will also identify and suggest an optimal value for the number of vehicle deposits/stations. Moreover, the tool will provide information concerning operating costs (e.g. cost for each use of e-scooter per kilometre) and generalised trip costs (e.g. average walking time/distance). Results will be provided in a numerical form but will be also visualised in the form of illustrative diagrams, reflecting the extent to which each parameter is affected by another (e.g. diagrams correlating fleet size with operating cost). In that way, the fluctuation of the results depending on the initial inputs, or the relaxation of certain constraints will be tractable.
Actors involved: • Micromobility service operators • Car sharing service operators • Department of a municipality tasked with issuing tenders for service (policymaker) • Transport planners supporting policy makers • Travelers (end-users)
Users: • Policymakers • Transport planners

Data inputs/needs:

- Total number of trips
- Population
- Acreage/area
- Operating cost per kilometre (moving assets & non-moving assets)
- Operating cost per vehicle per hour
- Average vehicles speed
- Average users walking speed
- Value of time of users
- Travellers' tolerance on access (waiting & walking) time (constraint)
- Weighting factors
- Standard deviation of demand

Process:



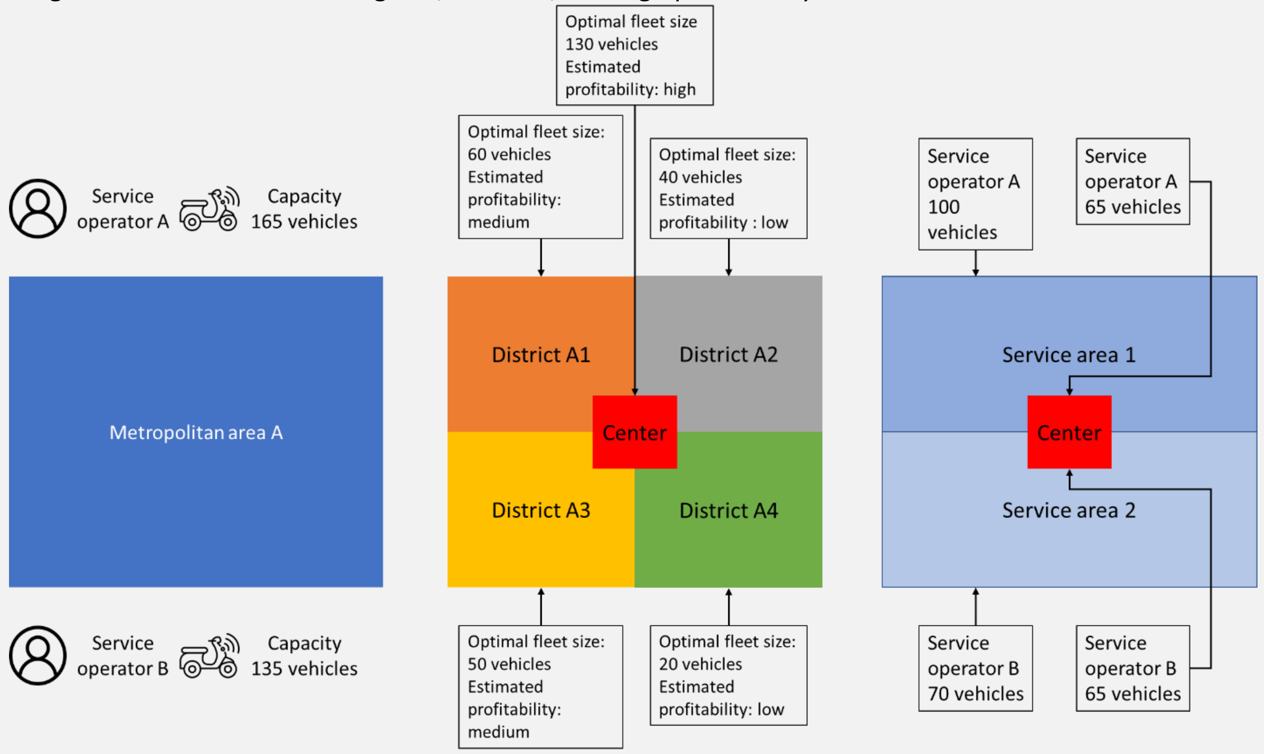
Data outputs:

- Optimal fleet size
- Optimal number of vehicle deposits/stations (occasional)
- Average walking time
- Average distance travelled
- Average waiting time
- Operating costs
- Rebalancing routes

Table 3: Technical description of Use Case 2

Use case number: 2
Use case title: Operative areas analysis
Use case description: The scope of the second tool to be integrated in the nuMIDAS toolkit is to provide support to policy makers of a metropolitan area towards the allocation of the operable fleet of multiple mobility service operators into specific service areas (operative areas). Similar to the UC1, focus will be given on micromobility and car-sharing services, such as bike-sharing (e-/kick-) scooter-sharing, and car-sharing services. The tool will seek to identify which service operators will be active in which service area and what amount of their capacity (i.e. operable fleet) will be assigned to each area. This is based on the premise that a large geographical area (i.e. a European metropolitan area) includes several districts in which the demand for shared-mobility services is either low, medium, or high. To this end, it is of high interest for policy makers to define service areas within the area of their jurisdiction in such a way so that: a) the level of provided services will be adequate for the end-users, b) the full area will be divided into service zones considering constraints related to equity (i.e. service operators should be treated equally and/or citizens should have equal access to shared mobility services), and c) the profit margin of service operators will be adequate to avoid economic losses, thus safeguarding the viability of operated services. A critical assumption to be made is that service operators are typically interested in serving smaller geographical areas of high population density with the aim of minimising operating costs and maximising their revenues (i.e. maximising their profits). In this respect, policy makers should make a trade-off between assigning to each service operator an attractive service area and a service area of lower attractiveness that should be served to ensure a minimum level of service. The tool will receive as input the value of the fleet size that should optimally be operated in each sub-area from the tool associated with the UC1. By that means, minimum and maximum operable fleet will be identified for each zone enabling the determination of the range of the decision variable, which in this case will be the amount of the capacity of each service operator allocated in each sub-area. Subsequently, the tool will be capable of approximating the profitability of service operators during a day for a given allocation of their capacity into specific sub-areas. The suggested value of the operable fleet per service operator and service will seek to optimise the level of service and the profitability of provided services in each area in a manner similar with the tools associated with the UC1case. Furthermore, and most importantly, the tool will seek a solution that will also minimise the difference in the level of service among the defined sub-areas and the difference in profitability among service operators, thus promoting equity. Taking into consideration that the land uses in European metropolitan are organised in such a manner so that a city centre exists in each city (and typically city centres constitute attractive areas), service operators may have to overlap within this area. The figure below provides a graphical illustration of the problem to be solved in the context of the UC2 of nuMIDAS project. In this example, Metropolitan area A can be divided in 4 districts that surround the city's centre. According to existing analyses (Use Case 1), the optimal fleet size of districts A1, A2, A3, and A4 are respectively 60, 40, 50, and 20 vehicles. Similarly, the optimal fleet in the city's centre is 130 vehicles. It is assumed that two service operators exist. Service operator A owns a fleet comprised of 165 vehicles, while service operator B owns a fleet comprised of 135 vehicles. An acceptable solution, in this respect, would be to assign district A1 and A2 to service operator A and district A3 and A4 to service operator B, while allowing both service operators to be active in the city's centre. The proximity of district A1 to district A2 is in favour of service operator A, given that the coverage of an area exhibiting spatial compactness enables the minimization of operating costs considering their reliance on the average distance travelled by all end-users within this area and the resulting need for service operators

to rebalance their fleet. The same holds true for service operator B. In addition, both operators are assigned with an area exhibiting low, medium, and high profitability.



Actors involved:

- Micromobility service operators
- Car sharing service operators
- Department of a municipality tasked with transportation planning (policymaker)
- Transport planners supporting policy makers
- Travelers (end-users)

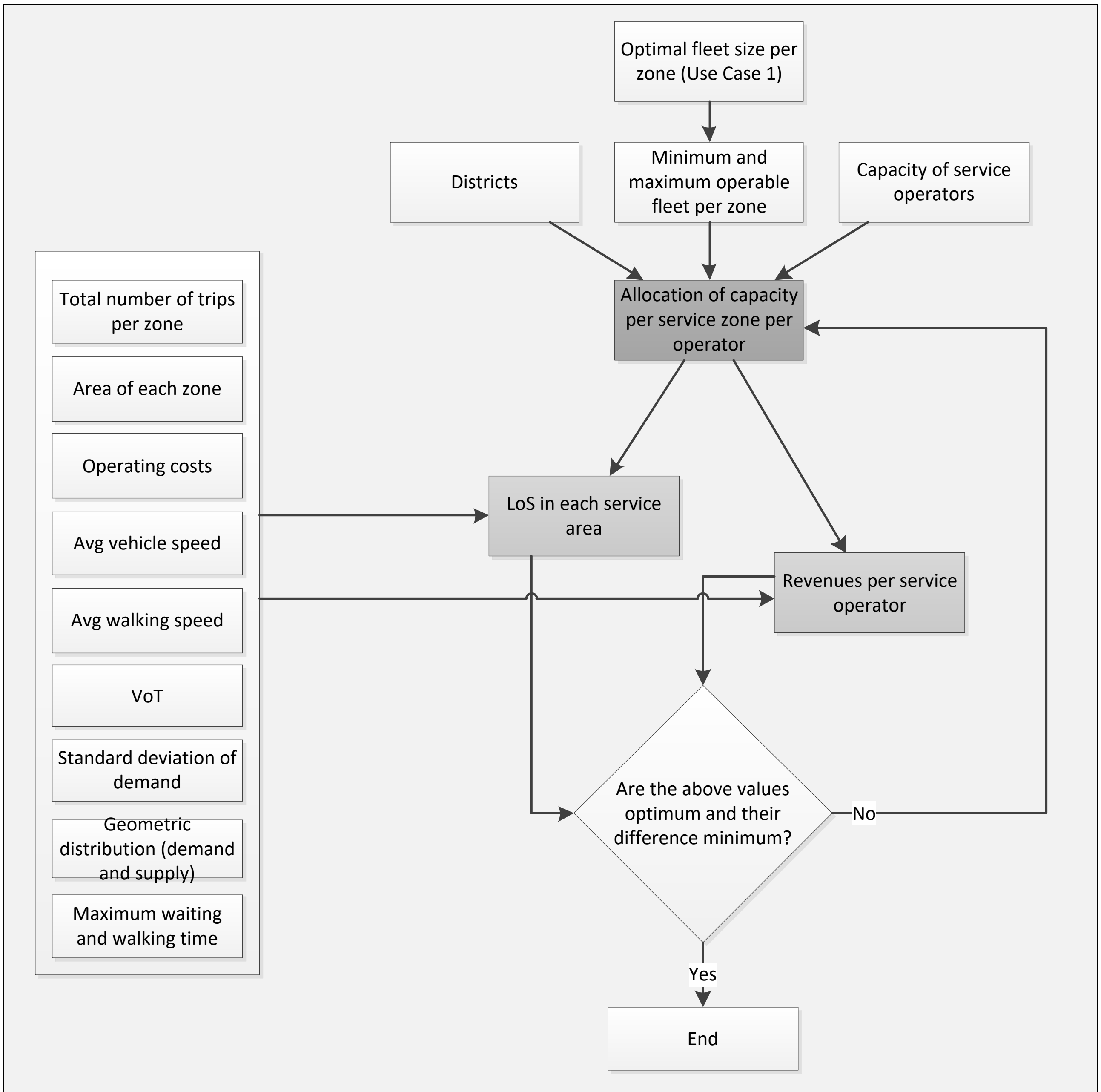
Users:

- Policymakers
- Transport planners

Data inputs/needs:

- Inputs of Use Case 1
- Number of available service operators
- Geofenced districts
- Optimal fleet size in each district (output of Use Case 1)

Process:

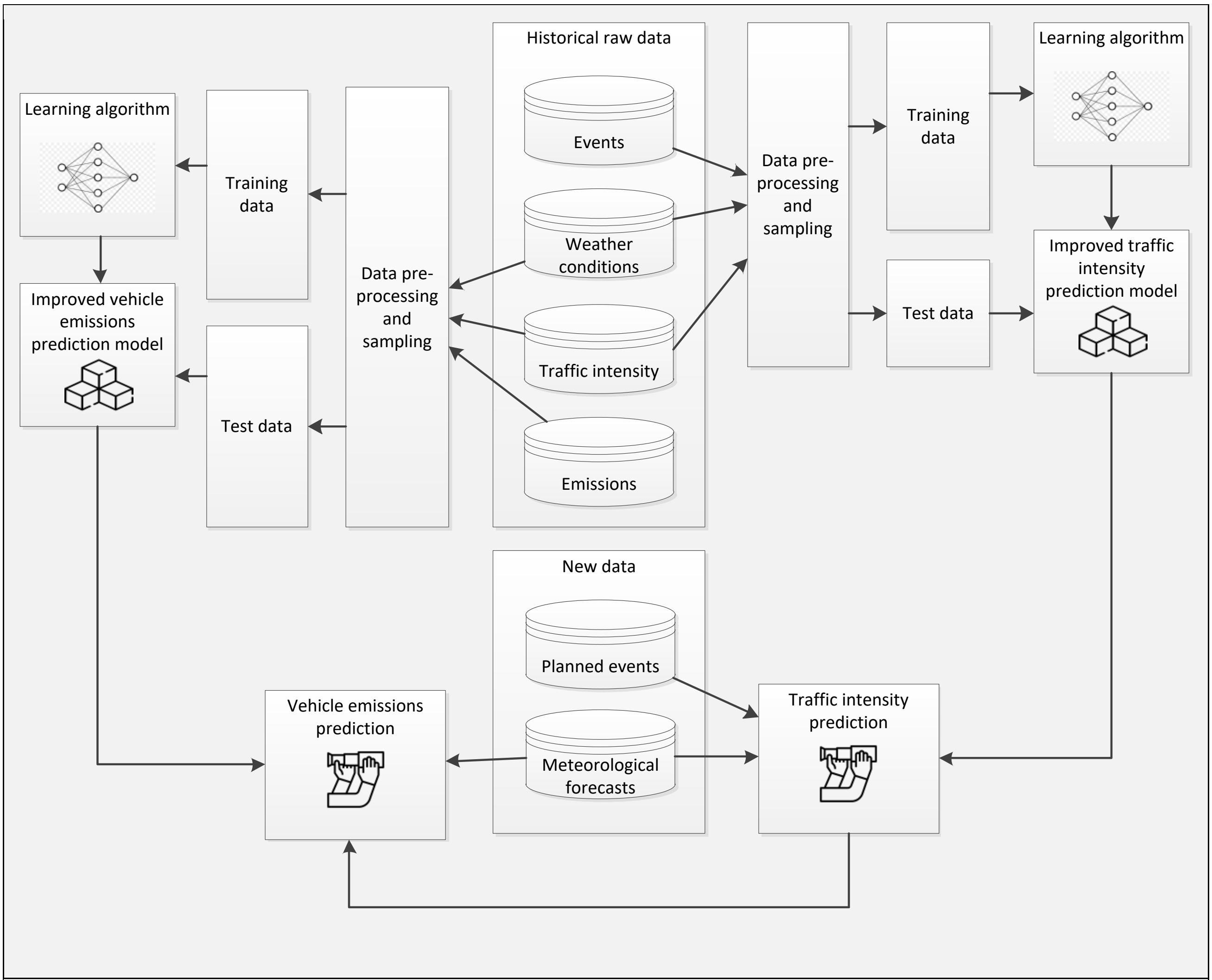


Data outputs:

- Definition of sub-areas
- Fleet assigned to each sub-area per operator
- KPIs for each area (e.g. related to level of service, operating costs, profitability)

Table 4: Technical description of Use Case 3

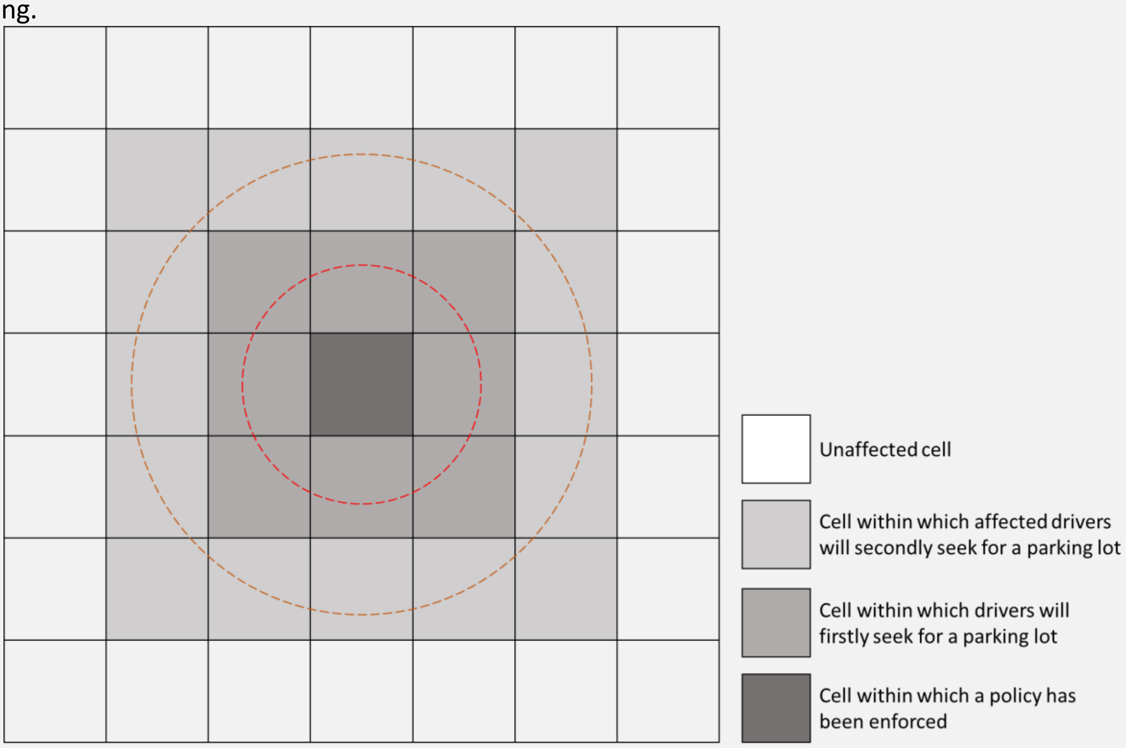
Use case number: 3
Use case title: Air quality and vehicle emissions analysis based on multi-source data
Use case description: The scope of the third tool to be integrated into the nuMIDAS toolkit is to support air quality and vehicle emissions analysis based on multi-source data. The tool will analyse and correlate various data sources providing information about traffic intensity, weather conditions, vehicle emissions, and events. The ultimate purpose is to forecast the effect of vehicle-induced emissions and weather on air quality in a short- to medium-term basis (i.e. time horizons covering at maximum the next 10 days). A critical consideration to be made is that the involved parameters are to certain extent interrelated. For instance, weather conditions may affect both traffic intensity and vehicle-induced emissions, while vehicle-induced emissions are affected by traffic intensity and weather conditions. This translates to the need for developing two models. The first one will provide an improved forecasting of traffic intensity based on traffic-related historical data, (planned) event-related data, and meteorological forecasts for the upcoming days. The second one will provide a forecast of vehicle-induced emissions based on traffic-related data and meteorological forecasts. In this respect, traffic-related information to be provided as an input to the second model will be the output of the first model. For both models to be developed supervised Machine Learning algorithms can be utilised (e.g. linear regression, logistic regression, artificial neural networks, deep neural networks). The following figure provides a schematic representation of the models to be developed. The tool to be developed in the context of the first variation of this use case will include diagrams correlating values from either historical or real-time data as well as values from the predictive models. Depending on the quality and spatial coverage of the provided data GIS-based visualizations will also be included. An added value scenario of this tool constitutes the estimation of the effect of traffic restriction measures simulated, for an instance, as an additional event type.
Actors involved: • Data providers (incl. traffic management centres) • Department of a municipality responsible for the enforcement of traffic restriction policies (policymaker) • Transport planners supporting policymakers
Users: • Policymakers • Transport planners
Data inputs/needs: • Historical records of traffic related indicators (e.g. speed, flow, density) • Historical records of weather conditions • Historical records of events • Historical emissions-related data • Meteorological forecasts • Planned events in the area of interest
Process:



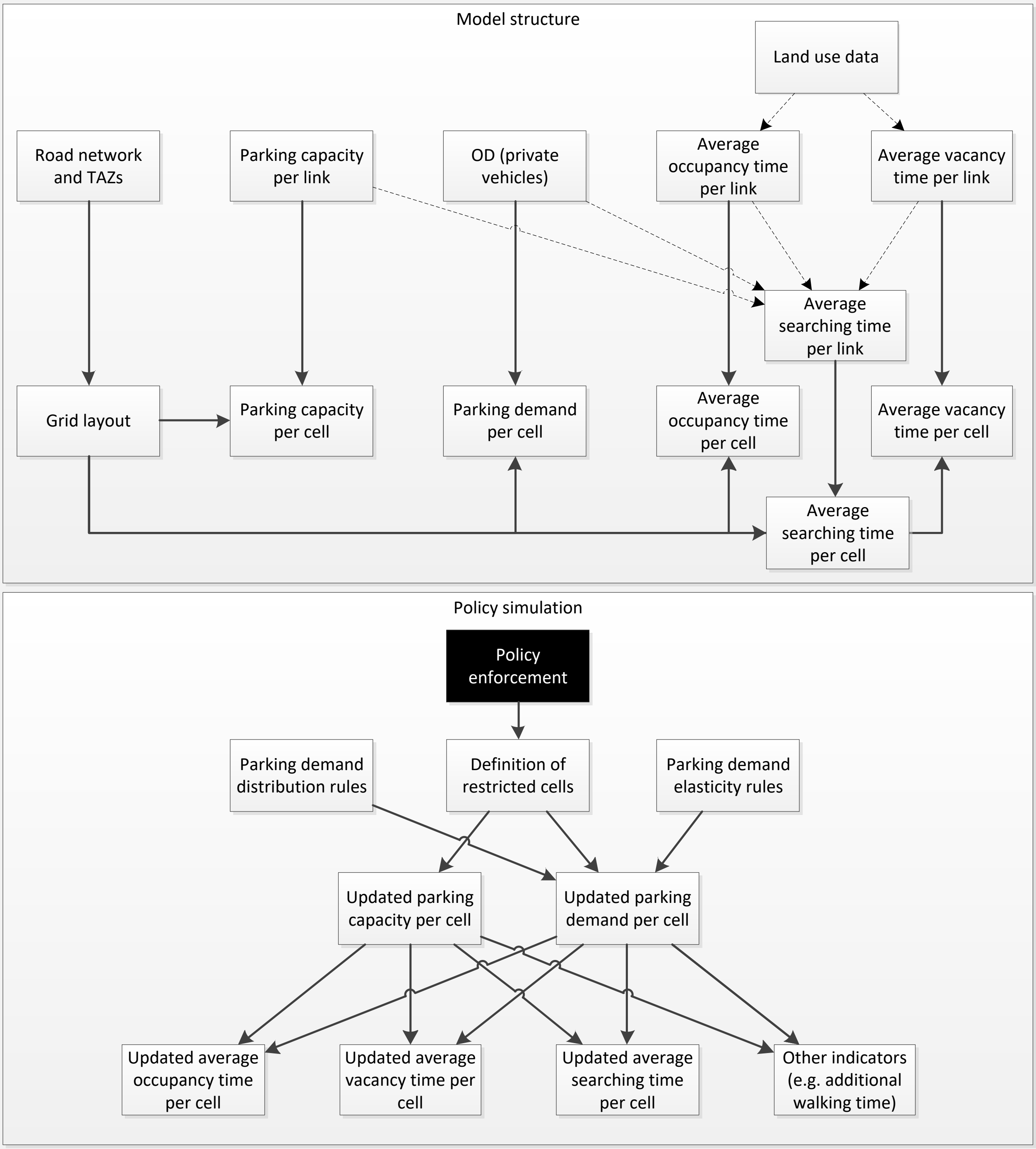
Data outputs:

- Traffic-related forecasts
- Emissions-related forecasts

Table 5: Technical description of Use Case 4

Use case number: 4
Use case title: Planning for parking
Use case description: The scope of the fourth tool to be integrated into the nuMIDAS toolkit is to support impact assessment of on-street parking restriction policies within inner cities. Such impacts may include a) the parking pressure relocated from the area in which a parking restriction policy has been enforced to adjacent areas, b) increases in parking searching time, and c) increases in trip costs (including increases in egress time). The operational logic of this tool will rely on the discretization of a road network using a grid comprised of cells of appropriate size and the use of key parameters, such as the average vacant time, the average occupied time, the average searching time, and the parking capacity of/in each cell. By that means, the tool will enable the simulation of enforcing a parking restriction policy in one or more grid cells and the assessment of its impacts on the remaining cells. This will be achieved by using appropriate rules and assumptions. Specifically, it will be assumed that vehicles influenced by the enforcement of a restriction policy will firstly seek for a parking place within the cells that belong to the perimeter of the affected one(s) and secondly within the cells that belong to the second perimeter. The figure below provides a graphical explanation. Moreover, the user of the tool will be able to select whether parking demand will be addressed as fixed or reduced based on the parking demand and capacity of adjacent cells. The impacts of a restriction policy will be assessed through the estimation of the updated value of key parameters by adopting a probabilistic approach and the estimation of other indicators, such as the increased egress time. The initial value of key parameters will be either user-defined or approximated by the tool itself using empirical evidence. For instance, the average occupancy and vacancy time can be approximated taking as input land-use data in each cell, while the average searching time can be approximated taking as input parking capacity, average occupancy and vacancy time, and vehicle travel speed when searching for parking. 

Actors involved: • Department of a municipality responsible for the enforcement of parking restriction policies (policymakers) • Transport planners supporting policymakers • Traffic police • Drivers
Users: • Department of a municipality responsible for the enforcement of parking restriction policies (policymakers) • Transport planners
Data inputs/needs: • Number and location of parking places • Average vacant time • Average occupied time • Average searching time • Network (grid)
Process:

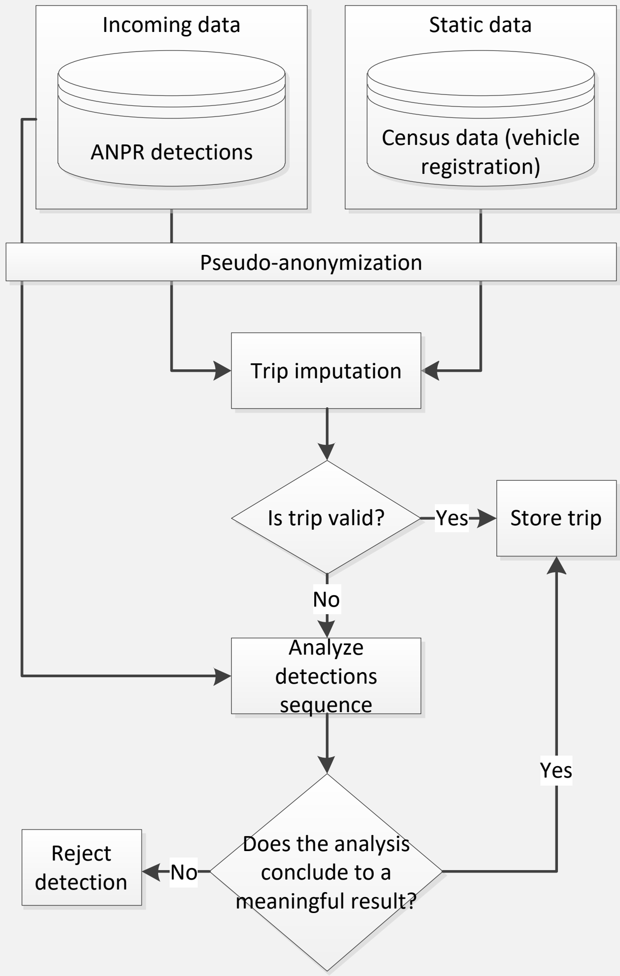


Data outputs:

- Difference in average vacant time
- Difference in average occupied time
- Difference in average searching time
- Additional walking time

Table 6: Technical description of Use Case 5

Use case number: 5
Use case title: Assessment of inflows and outflows in a metropolitan area
Use case description: The scope of the fifth tool to be integrated into the nuMIDAS toolkit is the estimation of in- and out-flows of a specific zone of a metropolitan area (e.g. low emission zone), i.e. from its boundaries to the remaining districts. These estimations will be based on data generated by Automated Number Plate Recognition (ANPR) systems coupled with census data (vehicle registration). The operational logic of this tool will involve the pseudonymization of license plate numbers (oriented to render the tool compliant with GDPR limitations) and the recognition of the origin and destination of their corresponding vehicles by associating the location of the (last) license plate detection with the location of the license plate's registration. With the aim of identifying not valid trips the tool will make use of a "taboo table" that will include OD pairs that are candidates for being addressed as not valid. For these detections, the tool will seek to identify valid origins and destinations by analysing the detections sequence of the corresponding pseudonymised license plates (i.e. if a vehicle is successively detected within an acceptable time interval at three points along a route, then the first point will be addressed as the trip origin and the last point as the trip destination). The outputs of the tool will include three dimensional (3D) OD matrices, including the origin of each vehicle, the city/district where the vehicle is registered (or other information), and its destination. The ultimate purpose of this tool is to deliver analytic data towards the improvement of transport planning within a metropolitan area, including the enhancement of park and ride services or the creation of new routes for existing public transport services.
Actors involved: • Data providers (e.g. traffic management centres) • Department of a municipality responsible for the enforcement of mobility policies or for transport planning (policymakers) • Transport planners supporting policymakers
Users: • All actors
Data inputs/needs: • ANPR system detectors' location (once during initialization) • ANPR system detections (including timestamp and station ID) • Census data (vehicle registration)
Process:

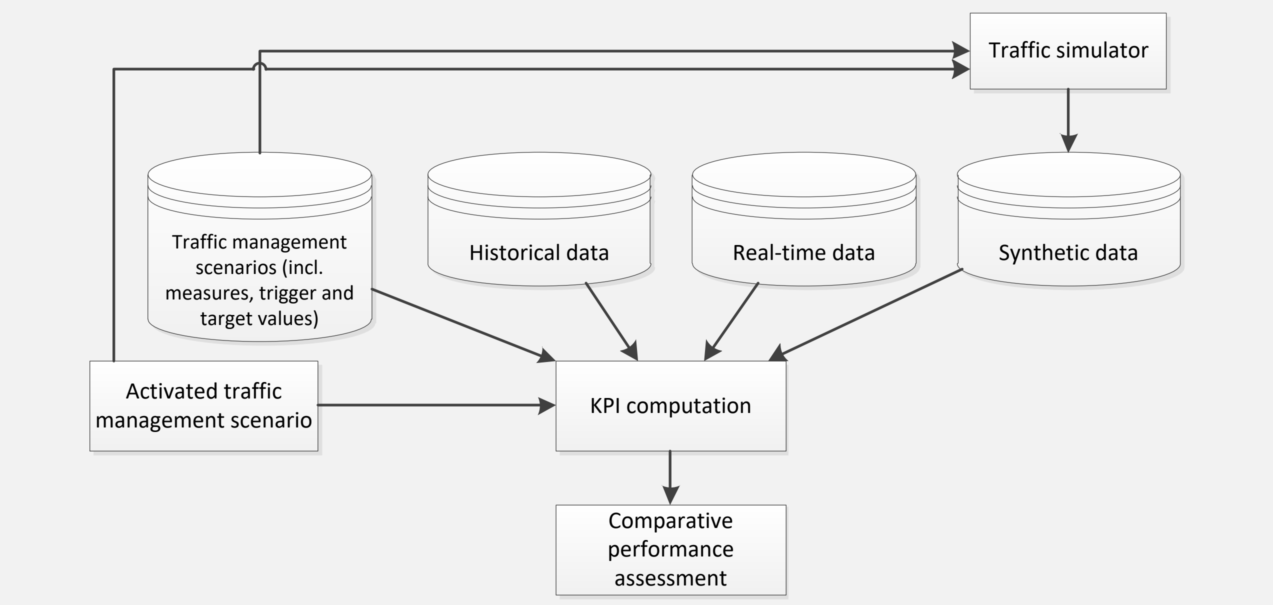


Data outputs:

- (3D) OD matrices

Table 7: Technical description of Use Case 6

Use case number: 6
Use case title: Assessment of traffic management scenarios
Use case description: The scope of the sixth tool to be integrated into the nuMIDAS toolkit involves the data-driven assessment of traffic management scenarios. The tool will allow the assessment of the performance of traffic management scenarios, including both conventional traffic management measures (e.g. traffic lights control or provision of information through Variable Message Signs) as well as novel and advanced technologies, such as C-ITS enabled dynamic traffic management (e.g. personalised provision of dynamic warnings, information, and guidance to drivers of connected vehicles). The tool will analyse Key Performance Indicators (e.g. related to speed, traffic flow, travel times, road safety, and emissions) that comprise trigger and target values of the activated traffic management scenarios, supporting the data-driven comparative assessment of the performance thereof. Required data includes historical, real-time, and synthetic datasets (e.g. road network status, traffic flow simulator data and others). The current approach for the objective of this tool is to support the assessment of both enforced (activated) traffic management scenarios and prospective traffic management scenarios. The former can be assessed through the comparison of KPIs quantified with the use of historical and real-time (incoming) data, while the latter can be assessed through KPIs quantified with the use of historical and synthetic data (derived from the simulation of a scenario in a microscopic traffic simulator). The scenarios to be analysed will include the modification of traffic signal control programs and the provision of route advice to drivers.
Actors involved: • Traffic Management Center (TMC) operators • Department of a municipality responsible for the enforcement of traffic management policies (policy-maker) • C-ITS service providers • Data providers • Transport planners supporting policy-makers
Users: • TMC operators
Data inputs/needs: • Database of traffic management scenarios (including trigger and target KPI values) • Currently active traffic management scenario • Historical data concerning speed, traffic flow, and travel time • Real-time or synthetic data concerning speed, traffic flow, and travel time
Process:



Data outputs:

- KPIs indicating the performance of activated traffic management scenarios

5.3 UML mock-ups

As outlined in Section 4.2, the outcomes of the analysis and the textual description of each use case executed in Section 5.2 are summarised into an intermediate representation complying to the principles of UML modelling (hereafter referred to as “UML mock-ups”). These UML mock-ups are presented in the current section (Figures 7-12) and are provided to the entirety of the project’s partners along with the technical description to identify the requirements for the nuMIDAS toolkit. The selected format of these representation complies to the behavioural approach of UML modelling that facilitate the the understanding of all incepted elements of the tools and their interrelation with the users and the goal(s) set.

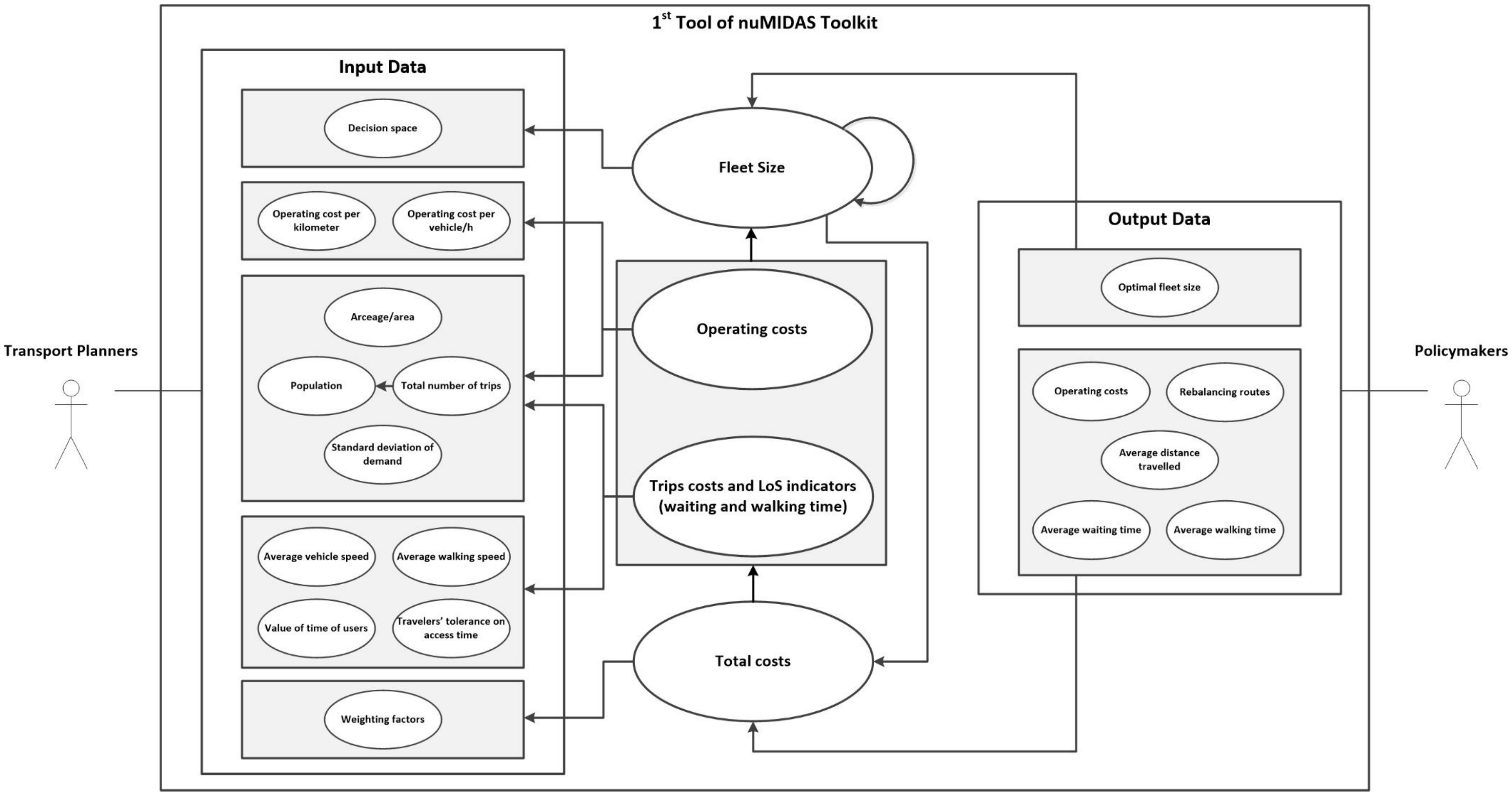


Figure 7: Intermediate UML representation of use case 1.

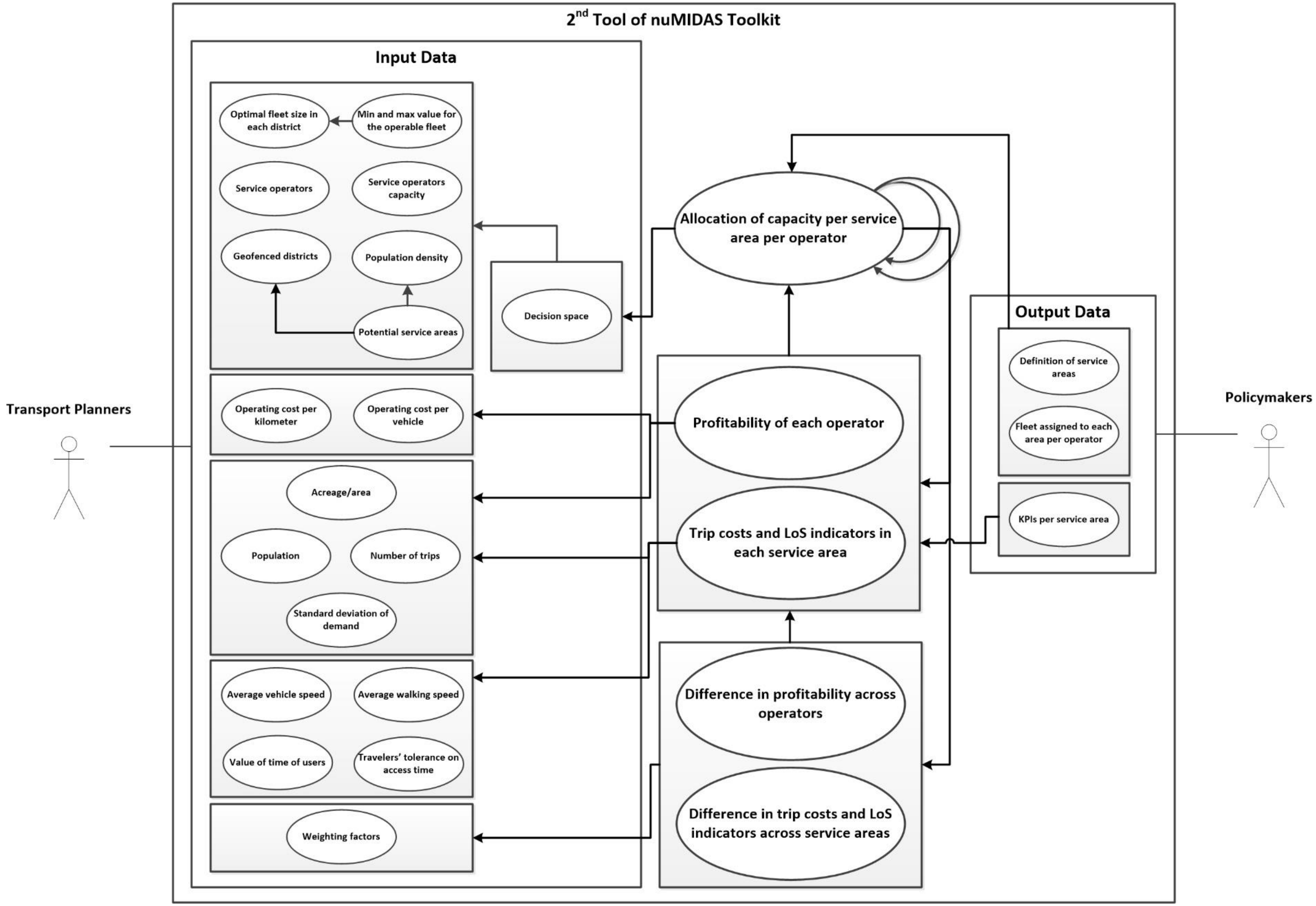


Figure 8: Intermediate UML representation of use case 2.

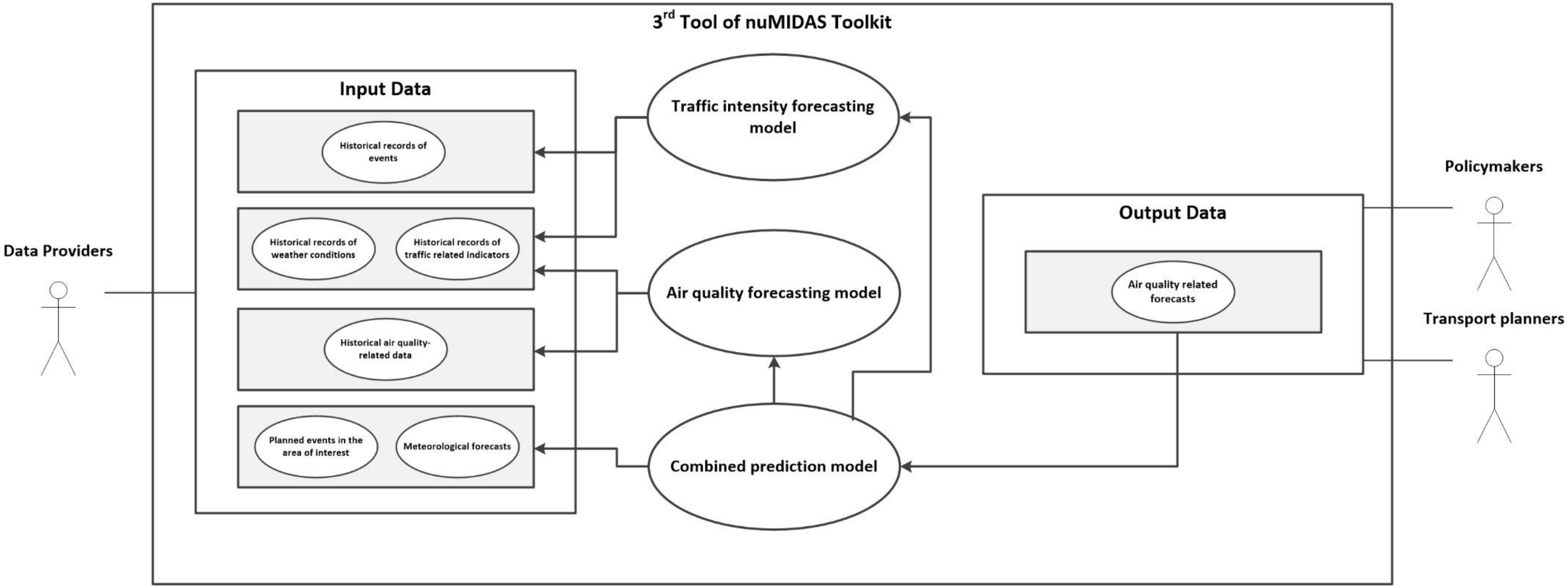


Figure 9: Intermediate UML representation of use case 3.

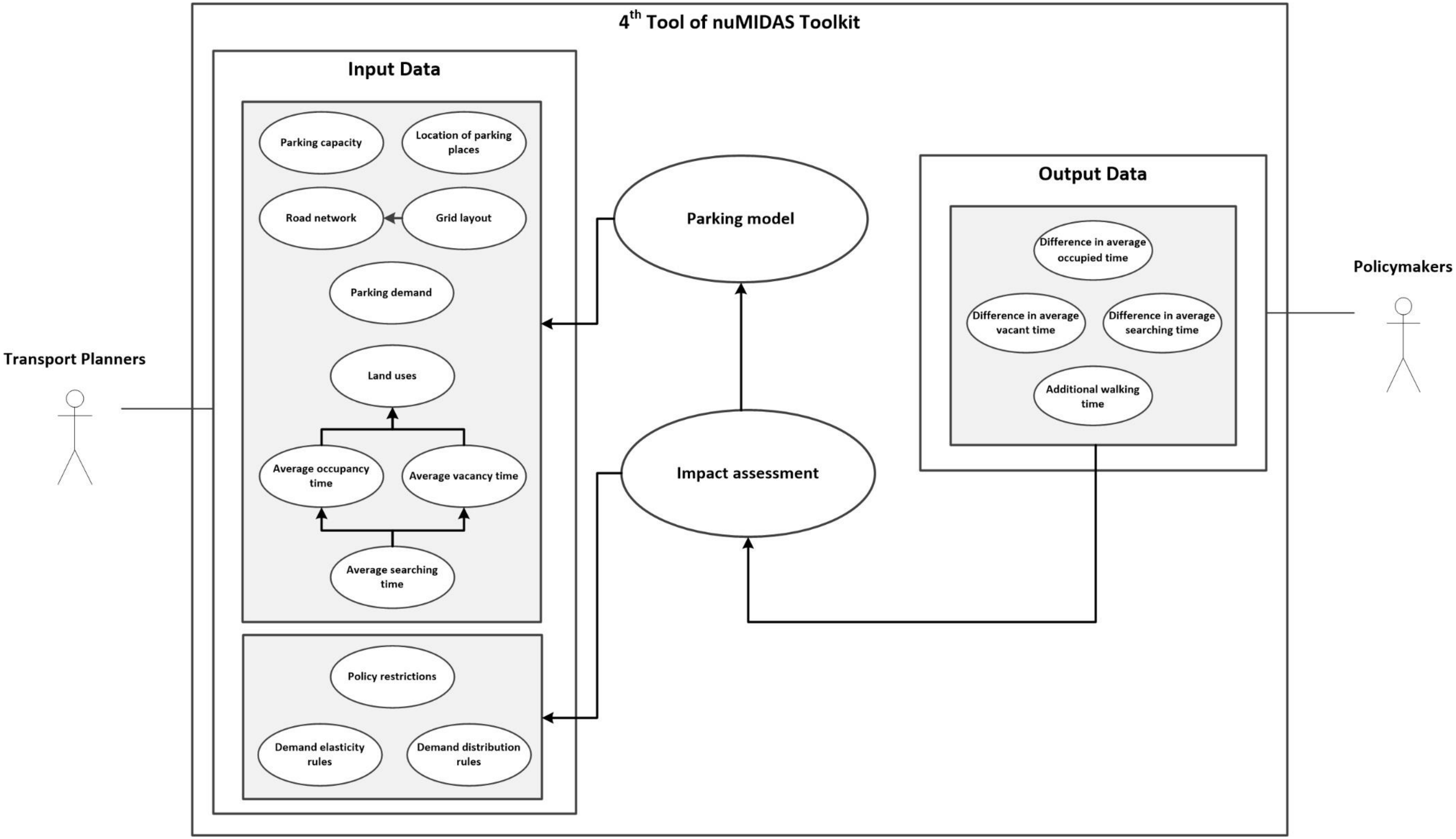


Figure 10: Intermediate UML representation of use case 4.

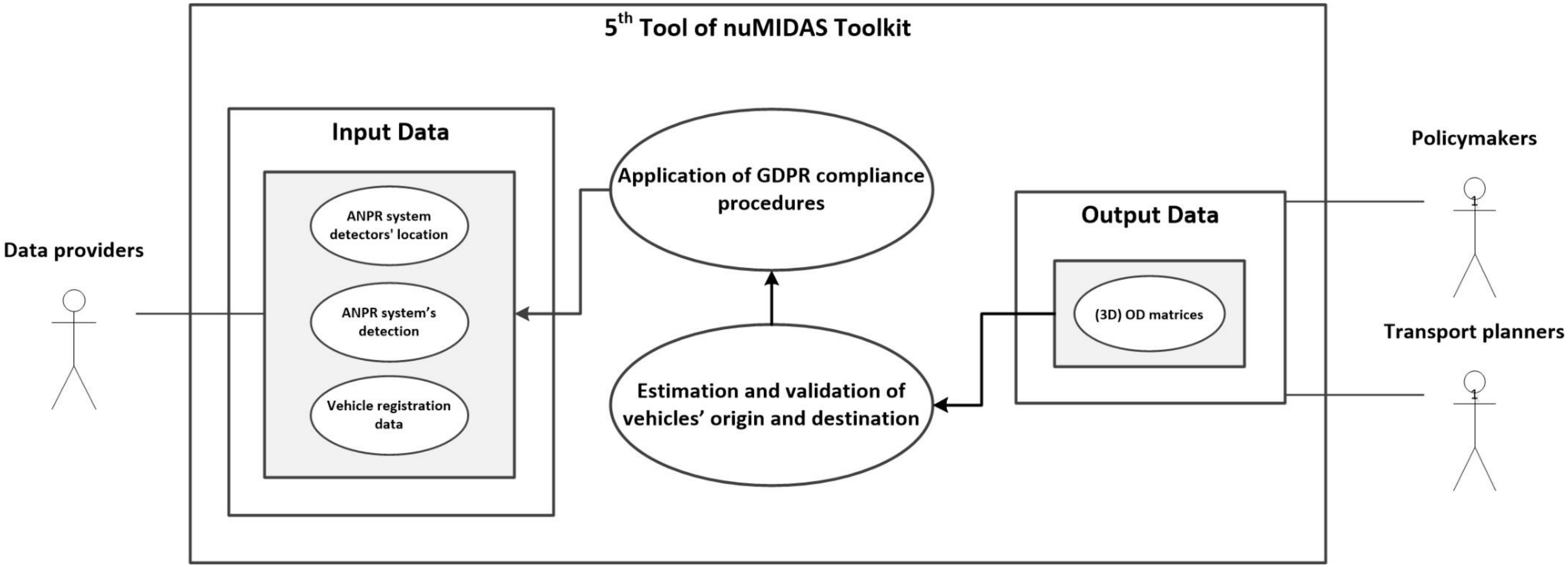


Figure 11: Intermediate UML representation of use case 5.

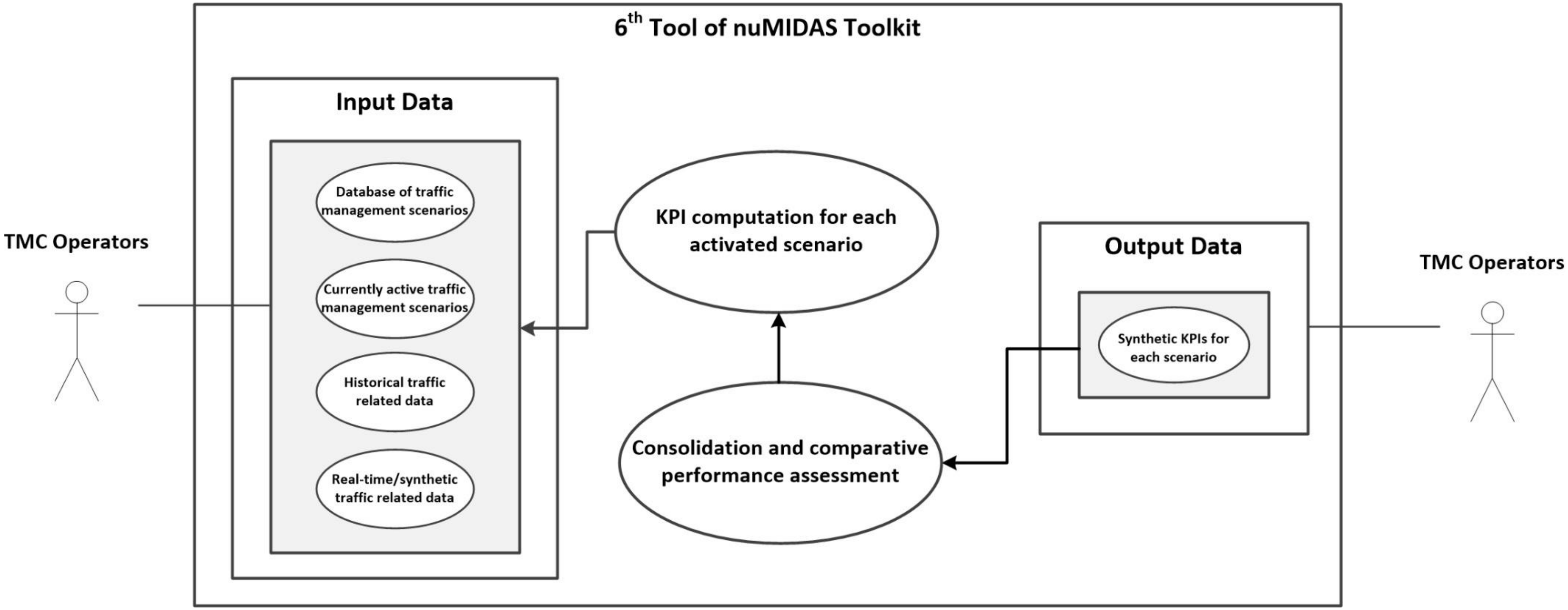


Figure 12: Intermediate UML representation of use case 6.

5.4 Requirements identification

According to the described methodology in Section 4.2, which aims to extract the main requirements for the toolkit, this part of the document presents the final requirements segregated in two main categories/types. Specifically, the final requirements are segregated into functional and non-functional ones. The former describe what the toolkit shall be able to do or shall not do, while the latter describes how the toolkit should function in several circumstances. Additionally, each requirement is associated with the corresponding use case(s) or the user interface (UI) of toolkit's dashboard. Finally, each requirement is accompanied by a description which briefly shows what should be included in the toolkit to be developed and the level of the priority of each requirement, discerned into low, medium, high. The results are presented in a tabulated form which is shown below (Table 8).

Table 8: List of identified requirements for the nuMIDAS toolkit.

ID	Type	UC1	UC2	UC3	UC4	UC5	UC6	UI	Description	Priority
F-1	Functional							X	The Dashboard of the NTK should have at least the following functions: login-logout, configuration, management, presentation, toolkit interface, service	High
F-2	Functional							X	A menu or sidebar enables the user to change to different screens within the service	Medium
F-3	Functional							X	The dashboard is service oriented. A user with access to multiple service can changes between services	Low
F-4	Functional							X	Within services, projects can be defined with rolls of users within the service	Medium
F-5	Functional							X	Configuration can contain settings for reference period, periods of day, reference values for KPI's, selection of relevant locations, measurement points etc., organised per project	Medium
F-6	Functional							X	Management allows the administrator to configure users, rolls, accessibility, services	Medium
F-7	Functional							X	Presentations of relevant information, data and KPIs representation are available in graph's bar plots, geographical representation etc.	High
F-8	Functional							X	From the dashboard, within a project, a calculation can be started by filling in necessary parameters and activation of the calculation	Medium
F-9	Functional							X	The (aggregated) results of a calculation will be saved within the project into a slot	Medium
F-10	Functional							X	The number of slots will have a maximum (e.g. 10) and can be	Medium

ID	Type	UC1	UC2	UC3	UC4	UC5	UC6	UI	Description	Priority
									overwritten	
F-11	Functional							X	Users will see a notification that a new calculation is underway during usage of the dashboard	Medium
F-12	Functional							X	The user who started the calculation can receive a notification within the dashboard that the calculation is finished and the results are available	Medium
F-13	Functional							X	Only one calculation can be activated at any time within a project	Medium
F-14	Functional							X	Only the project owner can start a calculation or release a calculation of another user	Medium
F-15	Functional							X	The dashboard can be equipped with a real-time tabulation showing most recent retrieved (live) data	Medium
F-16	Functional							X	Ready and available data will be presented within seconds in the representations	High
F-17	Functional							X	A geographic representation can be panned and zoomed	Medium
F-18	Functional							X	Where applicable information will be shown by hoovering or clicking on an object	Medium
F-19	Functional							X	Multiple layers can be shown when applicable and can be enabled or disabled	Medium
F-20	Functional	X							The NTK should be able to calculate the optimal fleet size	High
F-21	Functional	X	X						The NTK should be able to calculate the operating and trip costs	High

ID	Type	UC1	UC2	UC3	UC4	UC5	UC6	UI	Description	Priority
F-22	Functional	X	X						The NTK should be able to calculate the Level of Service indicators (waiting & walking time)	High
F-23	Functional		X						The NTK should be able to define operative (service) areas	High
F-24	Functional		X						The NTK should be able to assign operable fleet per operative (service) area per service operator	High
F-25	Functional		X						The NTK should be able to calculate KPIs for each operative area	High
F-26	Functional	X	X	X	X	X	X		The NTK should be able to provide configuration options to its users for all inputs	High
F-27	Functional	X	X	X	X	X	X		The NTK should be able to use common standard formats for data input	High
F-28	Functional	X	X	X	X	X	X		The NTK should be able to handle and use multiple sources of data	High
F-29	Functional			X		X	X		The NTK should be able to handle and exploit historical (static) and real-time (dynamic) data	High
F-30	Functional			X					The NTK should be able to provide short- and mid-term air quality and traffic intensity forecasting	High
F-31	Functional				X				The NTK should be able to assess on-street parking restriction policies impacts on traffic	High
F-32	Functional					X			The NTK should be able to estimate the origin and destination of vehicle trips based on ANPR system detections and census data	High

ID	Type	UC1	UC2	UC3	UC4	UC5	UC6	UI	Description	Priority
F-33	Functional	X	X	X	X	X	X	X	The NTK should be able to pseudo-anonymise sensitive data for achieving GDPR compliance when needed	High
F-34	Functional						X		The NTK should be able to assess the performance of traffic management scenarios	High
NF-1	Non-functional	X	X	X	X	X	X	X	The NTK should handle data by applying state-of-the-art security standards on all transactions and data storage	High
NF-2	Non-functional	X	X	X	X	X	X		The NTK should be able to account for network sizes of large metropolitan areas	High
NF-3	Non-functional	X	X	X	X	X	X		The NTK should be able to provide its outputs with minimal computation time	High

6 UML model

This section presents the final UML model consolidating the entirety of information included in Section 5. This model is created using the Enterprise Architect platform[3]. The high-level (clean) model is presented in Figure 13, while Figure 14 depicts the actors involved in the ecosystem of the toolkit.

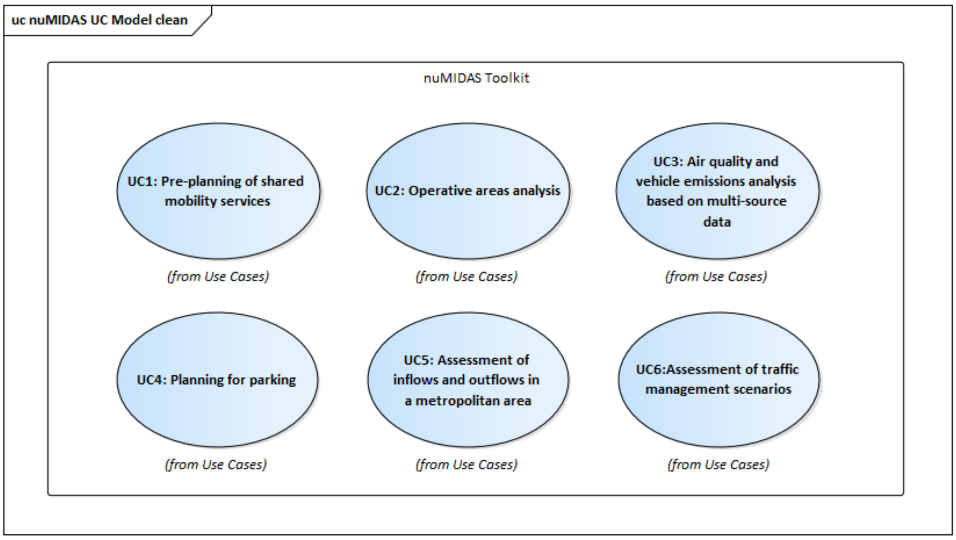


Figure 13: nuMIDAS UC model clean

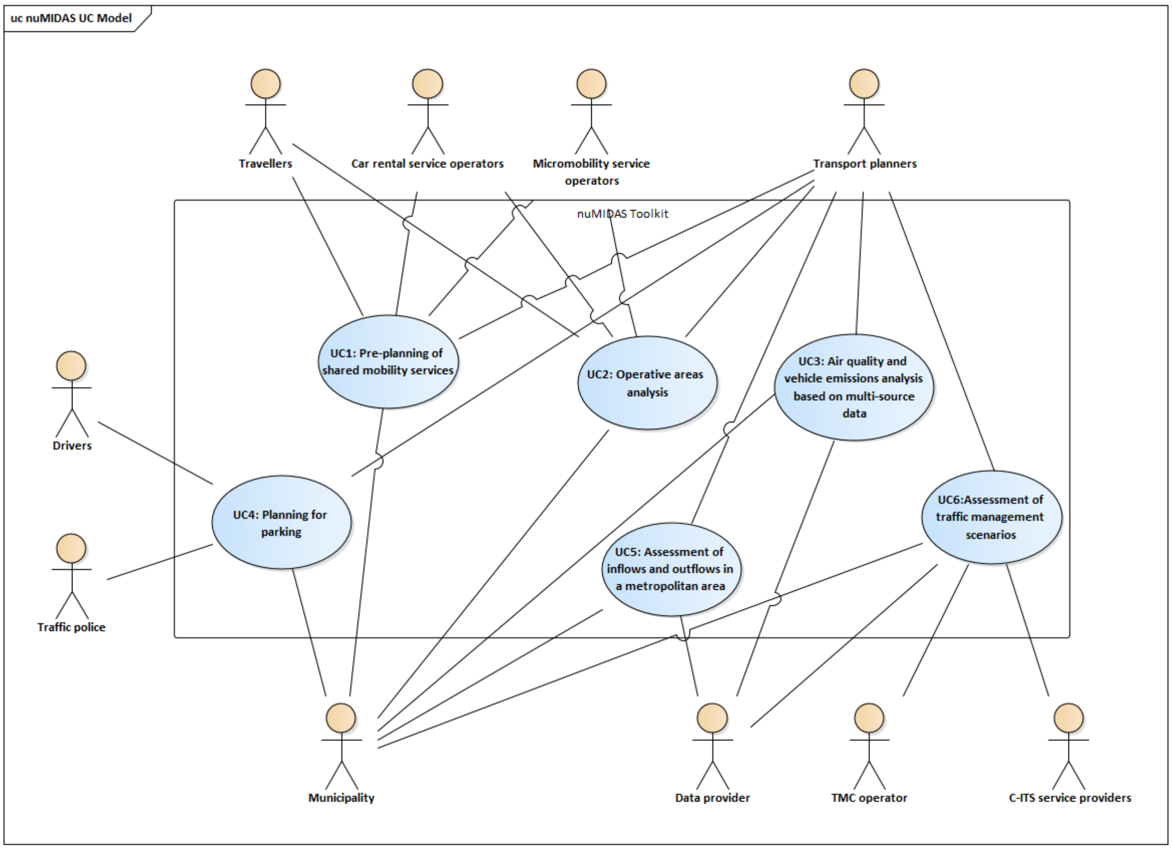


Figure 14: nuMIDAS UC model

[3] https://sparxsystems.com/

An overview of modelled requirements is presented in Figure 15. These requirements are compliant with those presented in Table 8.

The association of these requirements with the use cases of the toolkit are schematically presented in Figures 16-21. These figures represent the value or the goals that the actors involved in each use case wish to achieve.

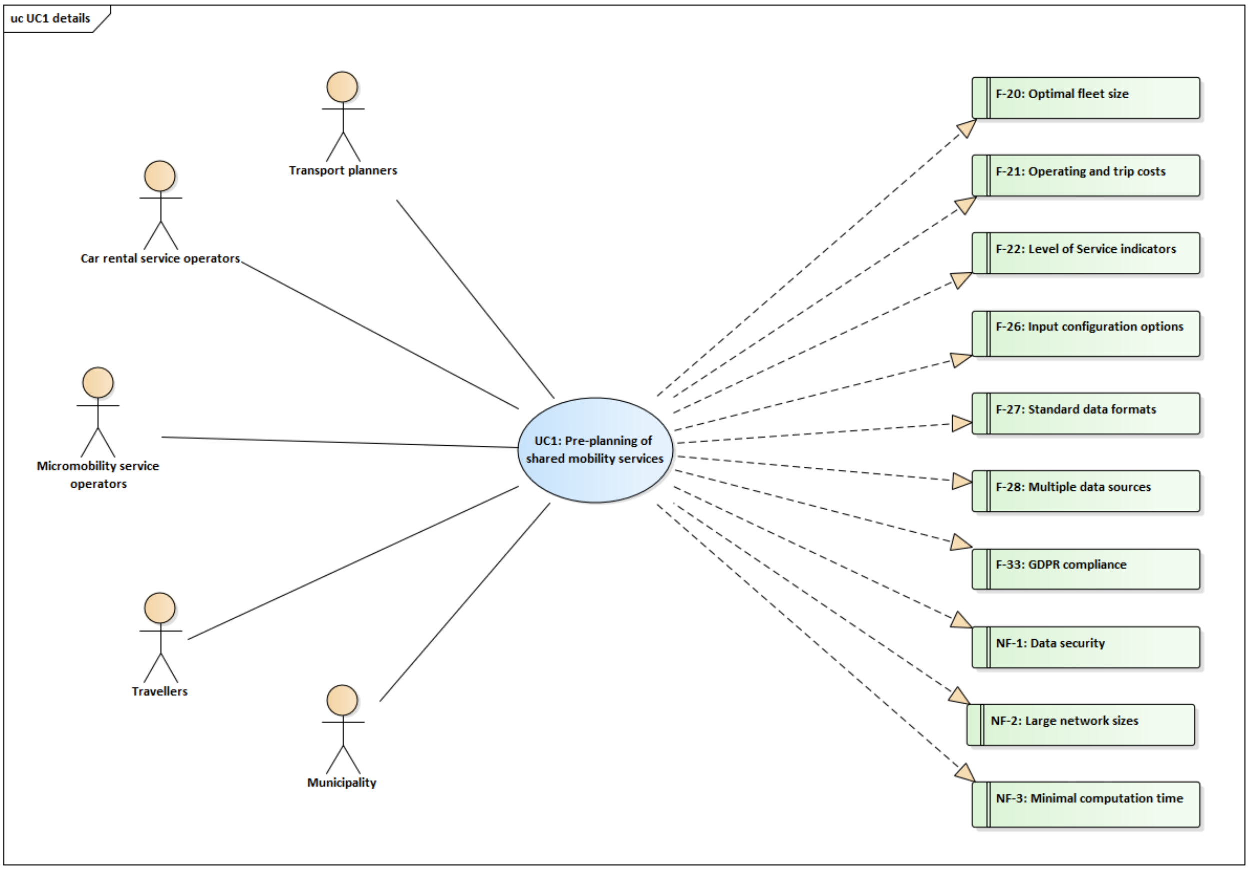


Figure 15: UC1 details

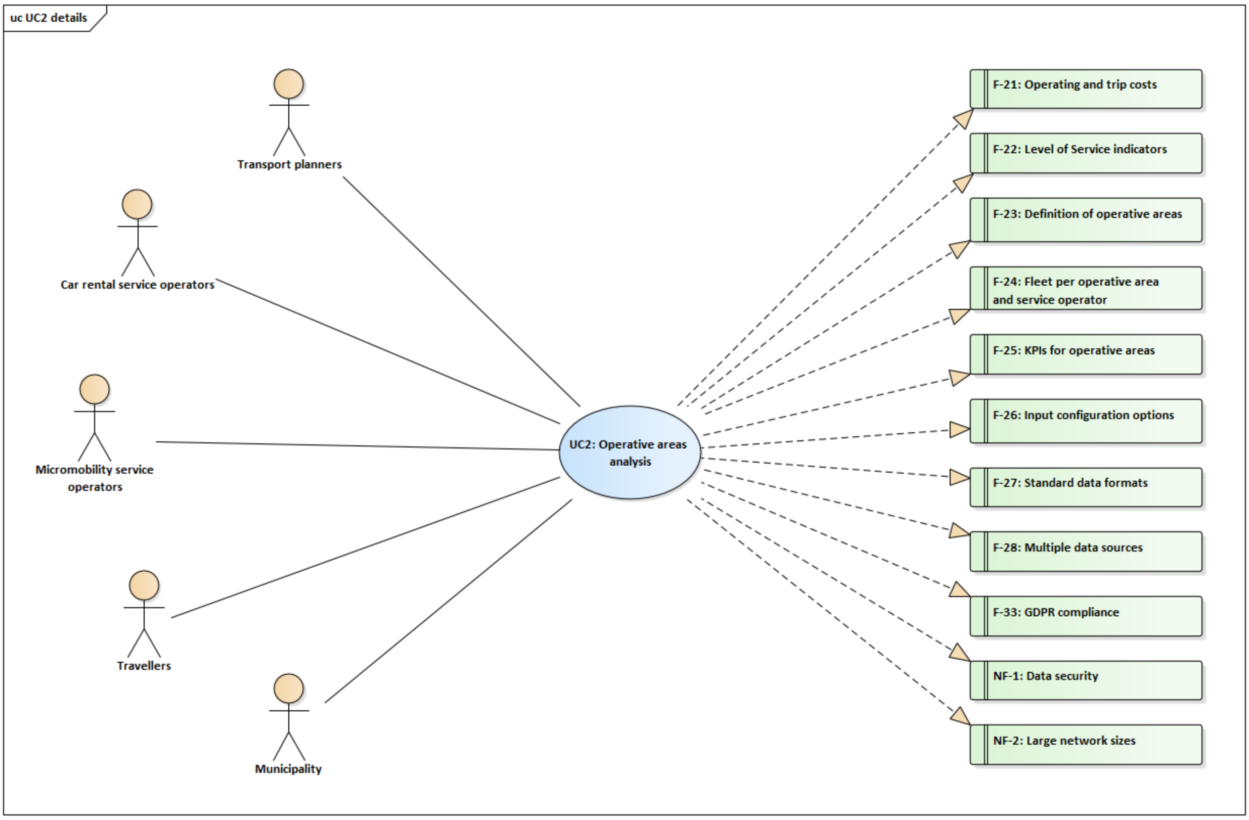


Figure 16: UC2 details

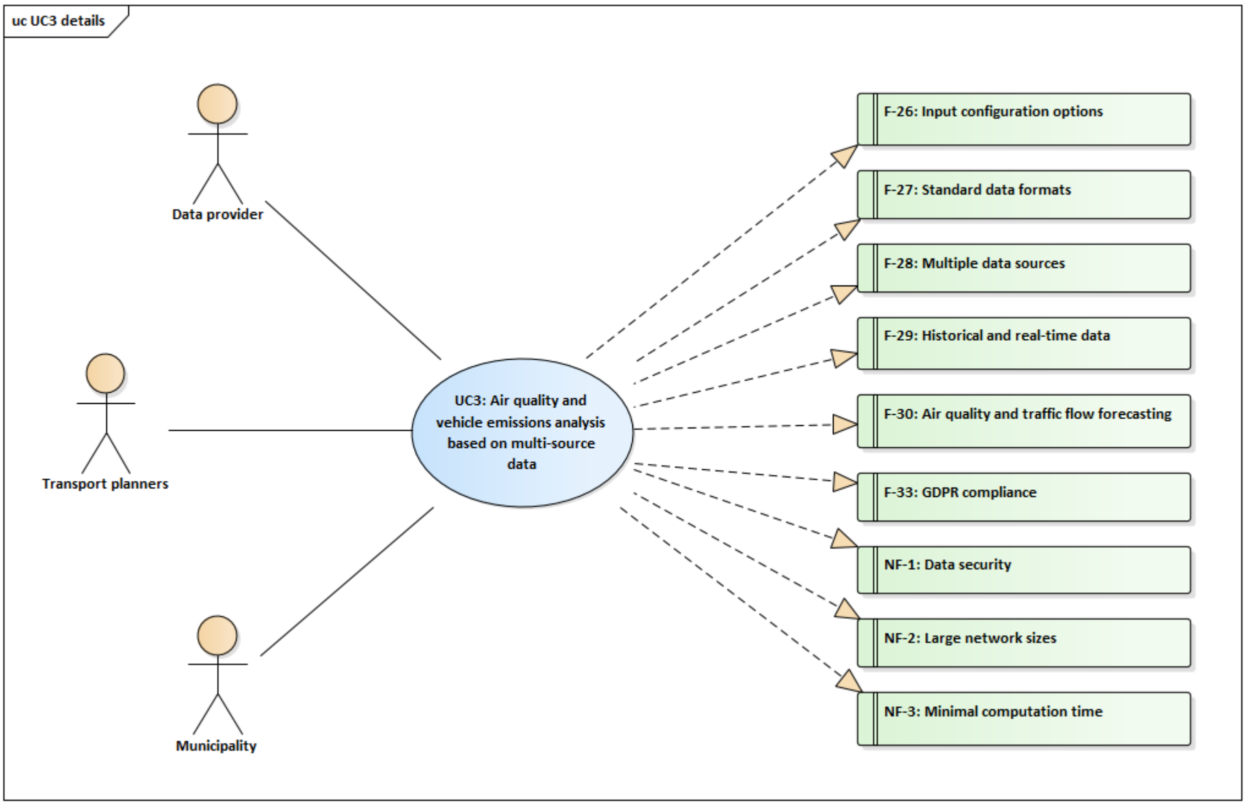


Figure 17: UC3 details

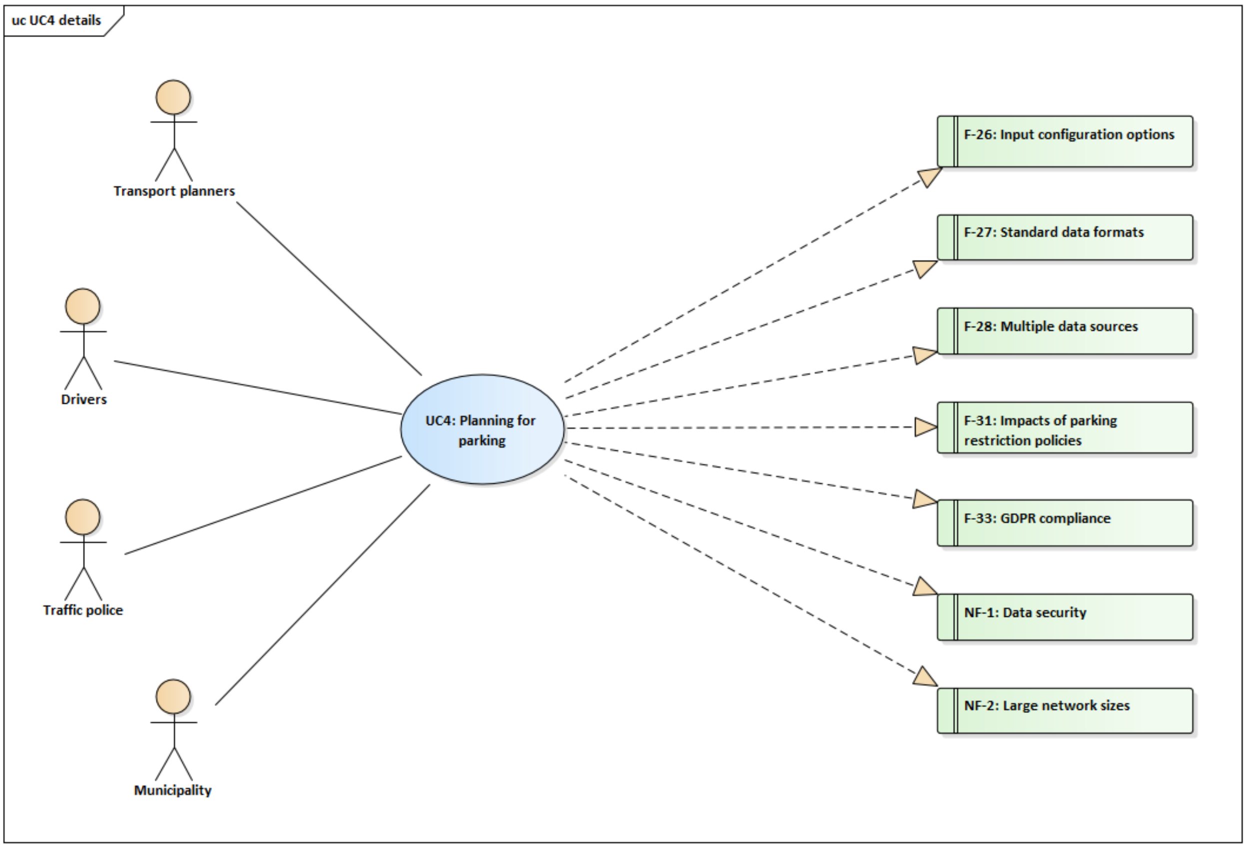


Figure 18: UC4 details

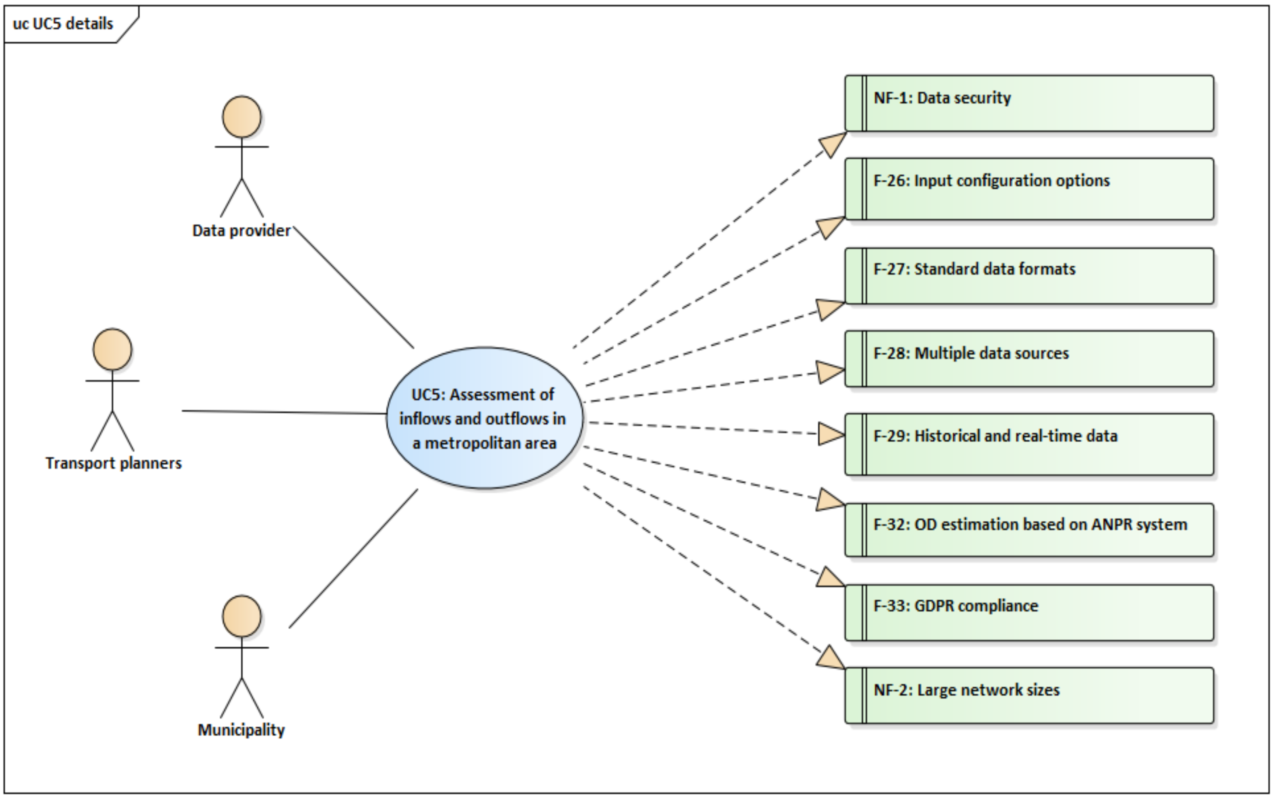


Figure 19: UC5 details

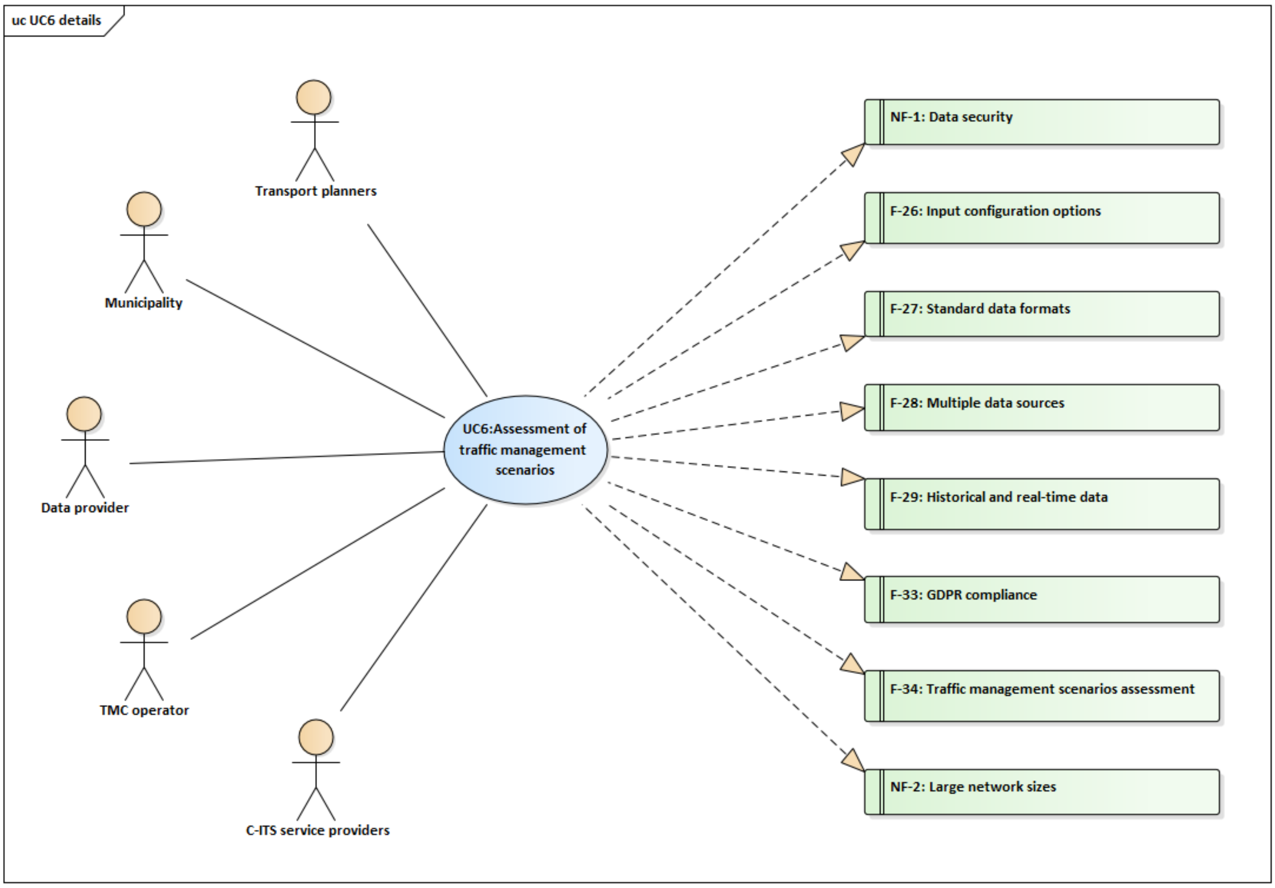


Figure 20: UC6 details

Finally, Figures 22-27 include the activity diagrams associated with each use case. These diagrams schematically represent the behaviour of the toolkit associated with each use case. In each diagram a control flow from a start point to a finish point is included, demonstrating the path sequence until the fulfilment of the target outcome.

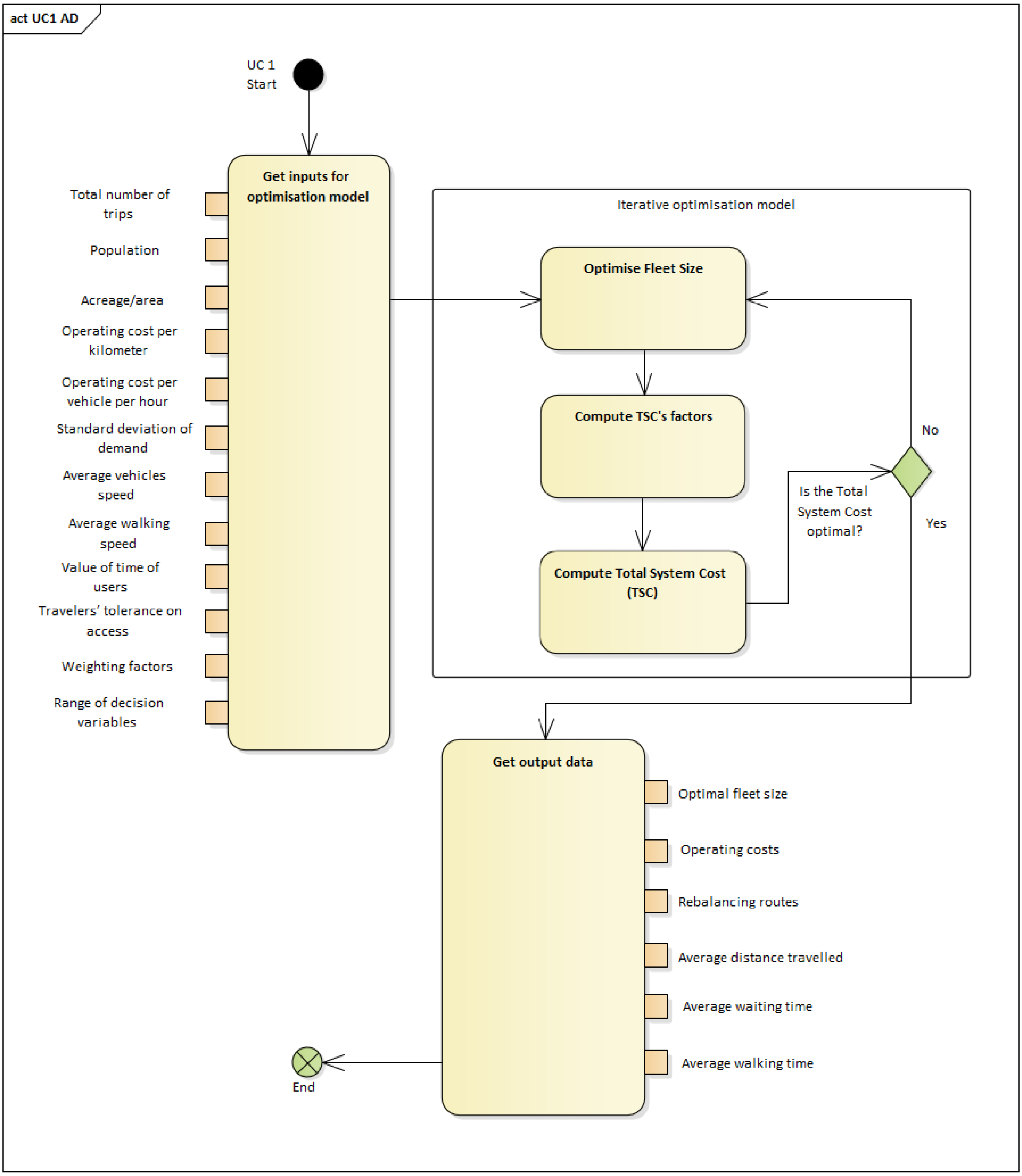


Figure 21: UC1 activity diagram

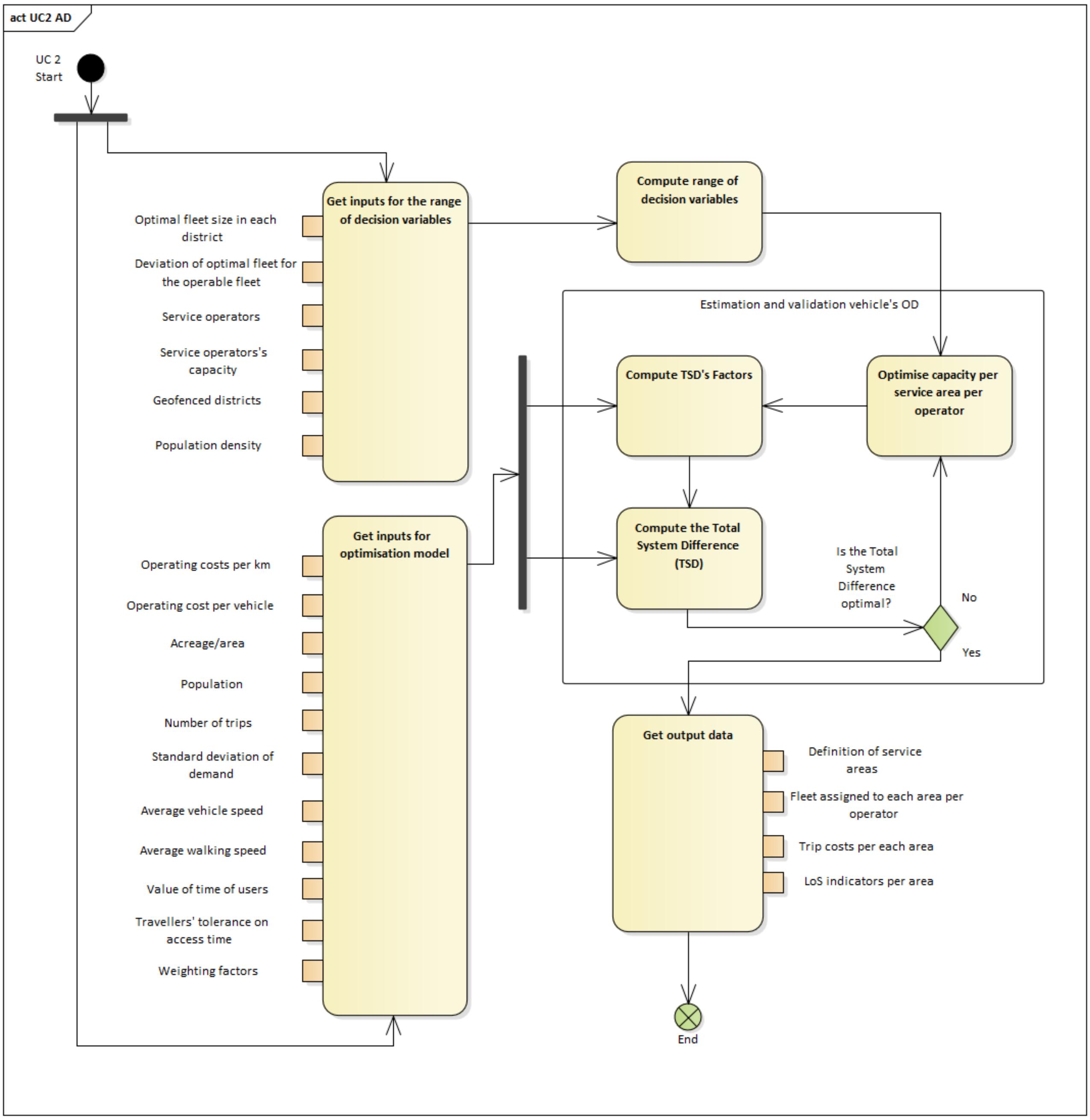


Figure 22: UC2 activity diagram

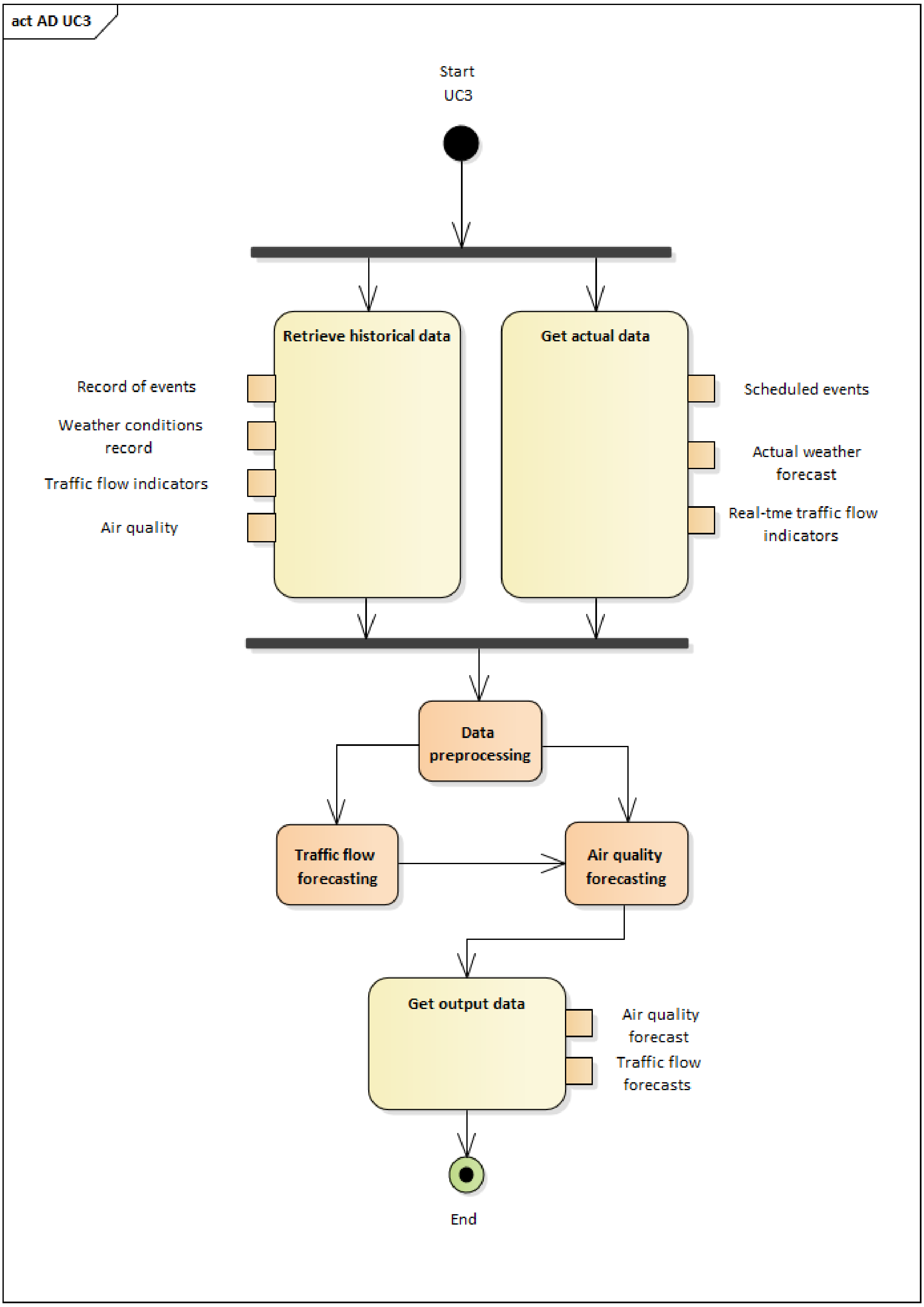


Figure 23: UC3 activity diagram

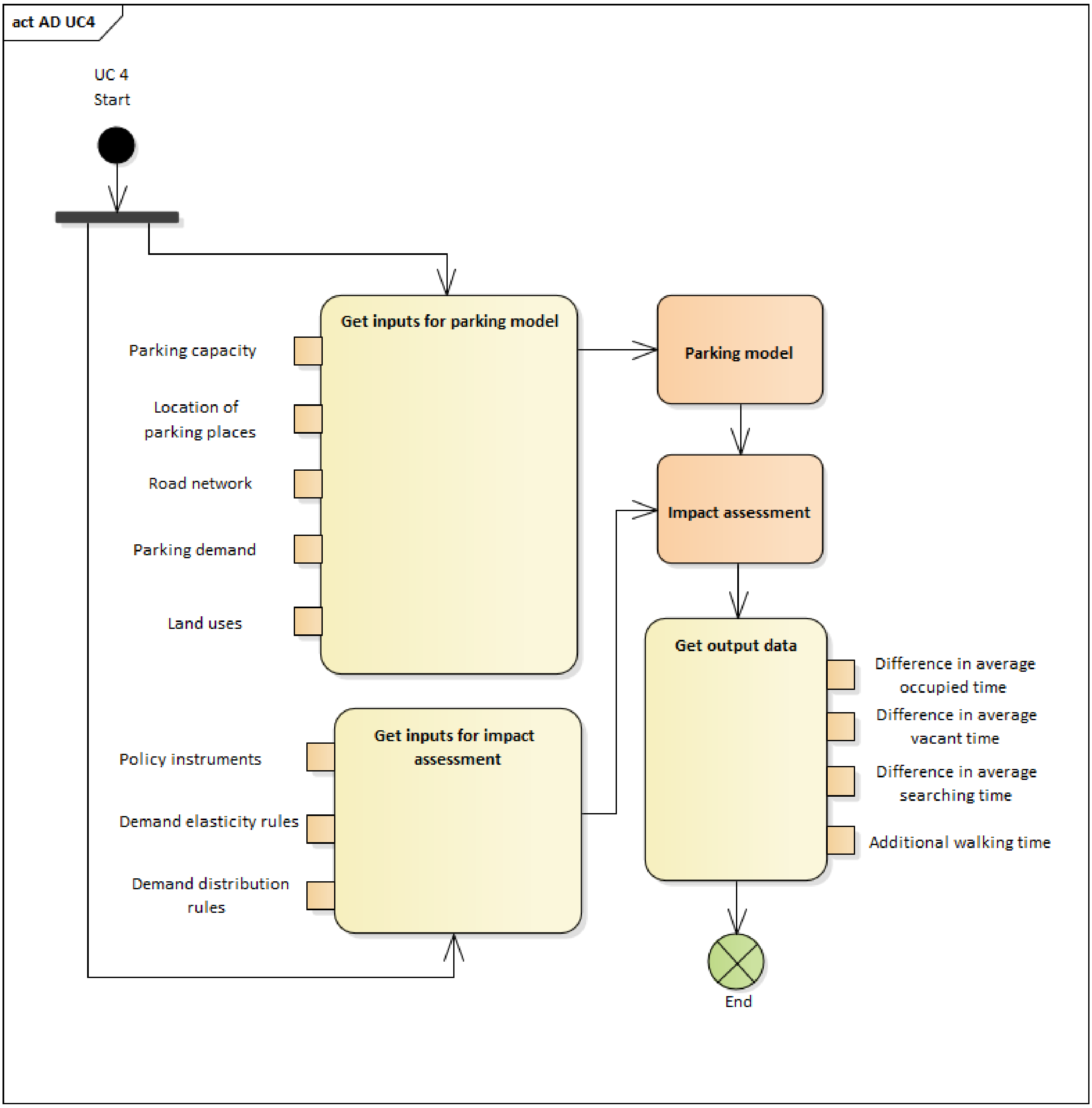


Figure 24: UC4 activity diagram

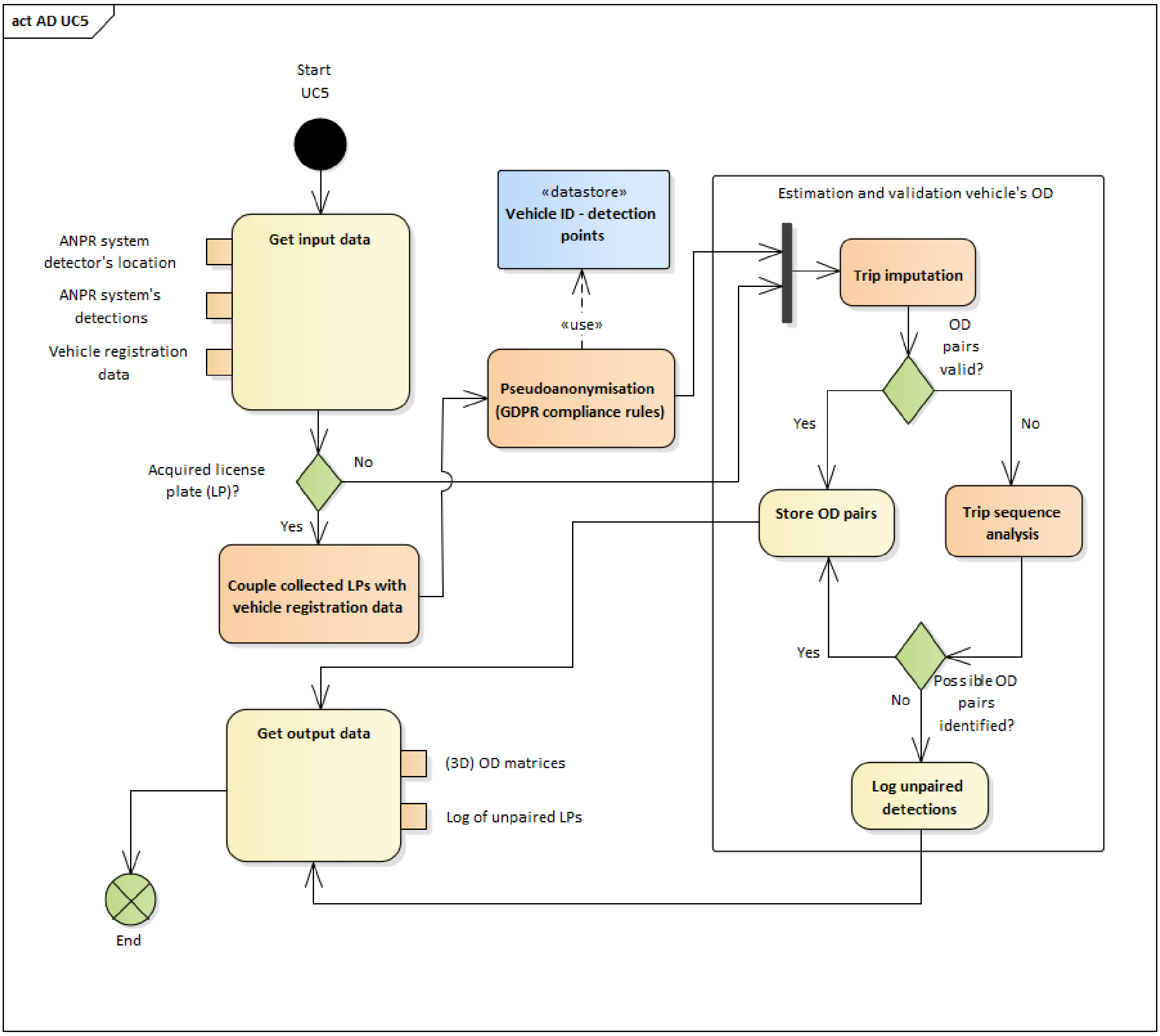


Figure 25: UC5 activity diagram

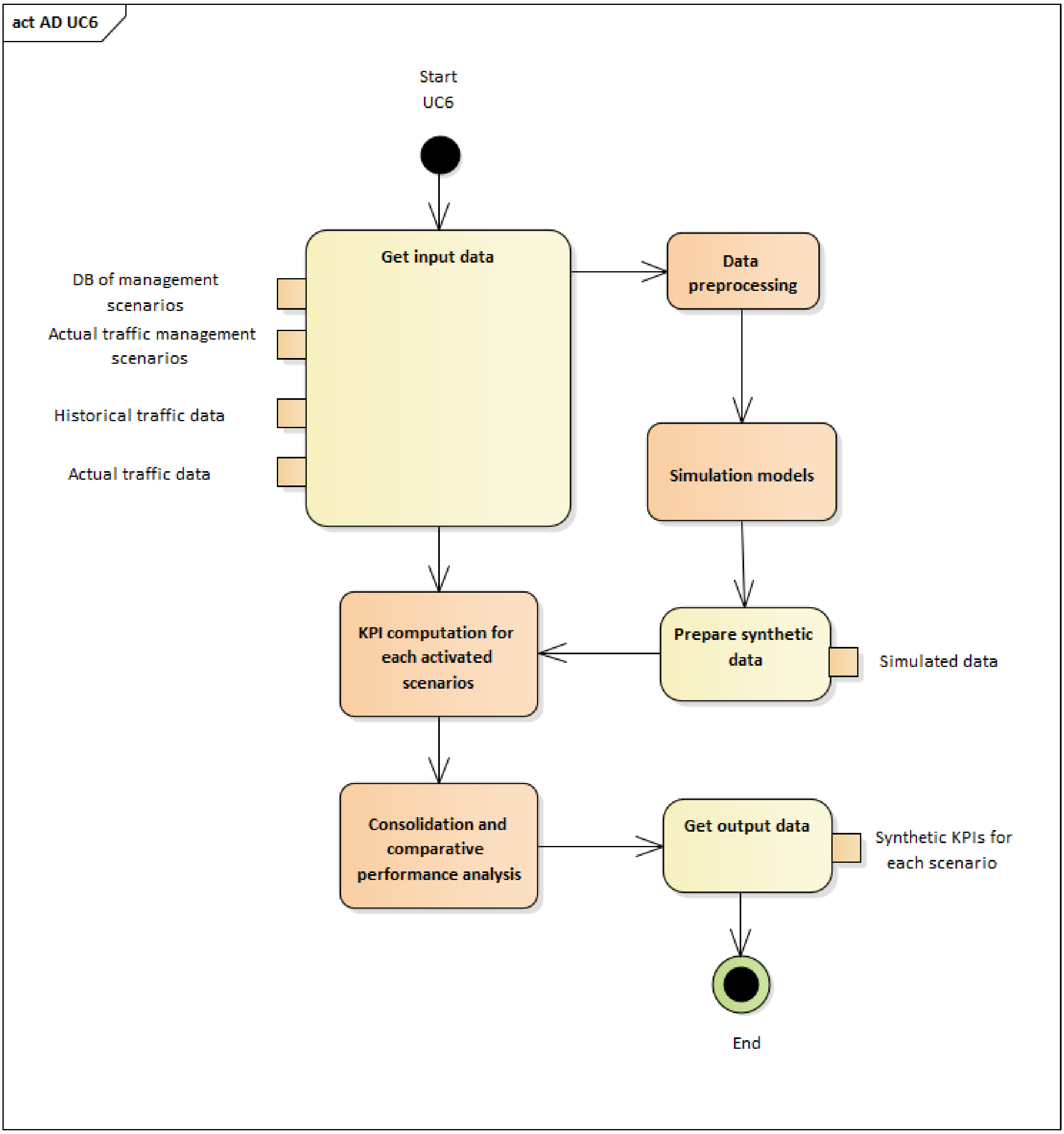


Figure 26: UC6 activity diagram

7 Concluding remarks

This deliverable provides an exhaustive analysis of the use cases that will play a focal role during the development of the project's toolkit. To this end, we have provided a brief discussion on the concept of use cases and approaches that are typically utilised for their analysis. Subsequently, we have explained our approach for defining the scope of each use case as well as the adopted methodology for their analysis. In brief, this methodology initiates with an analysis step utilising natural language. This step concluded to the technical description of each use case comprised of a) a brief, yet inclusive, description of the scope and goals of each use case, b) the identification of the actors involved, c) the identification of the targeted users, d) the identification of the required inputs, e) the schematic representation of the process flow, and f) the identification of the target outputs. The information included in these textual descriptions are, firstly, consolidated in one mock-up UML representation per use case and then handed over to the entirety of the project partners, who are asked to identify the requirements for the nuMIDAS toolkit. Finally, the derived requirements along with the details of each use case are integrated into the UML model of the nuMIDAS toolkit.

The process mentioned above led to the analysis of six use cases. The focus of the first is to support the calculation of the optimal fleet size of shared mobility services taking as input socioeconomic, mobility, financial, and service provision-related parameters and constraints. This calculation will rely on the optimization of an objective function reflecting both the interests of travellers and service operators. The UC2 case constitutes an extension of the UC1first one. Specifically, UC2 is fed with the output of the UC1 case to identify a minimum and maximum value for the operable fleet of shared mobility services in specific districts of a metropolitan area. The goal is, then, to combine these districts and define service zones into which a large geographical area can be decomposed. The last step is to identify the operable fleet in each service zone as well as the service operators that will be active in each zone, including the amount of their capacity that will be assigned in each zone. This use case will rely on the optimization of a multi-objective function, involving the maximization of the operators' profitability and the level of service in each zone, as well as the minimization of the differences among service zones and service operators in terms of both level of service and profitability, respectively. By that means, the derived solution will promote equity principles understood from both a travellers and service operators' perspective. The UC3focus on air quality and vehicle emissions analysis based on multi-source data. The ultimate purpose of this use case is to develop a tool that will correlate available data and support air-quality forecasting in a short- to medium-term basis, thus justifying and navigating the enforcement of relevant policies and policy instruments (e.g. access control for environmental reasons). The objective of the UC4 is to support the assessment of the traffic-related impacts of parking restriction, thus also facilitating the justification and navigation of relevant policy instruments (e.g. reduction of parking lots within inner cities). The UC5, on the other hand, involves the estimation of inflows and outflows between the districts of a metropolitan area using as input data generated from point-to-point detection systems and census data. Through this use case a metropolitan area can refine and adapt access control policies and policy instruments as well as to better plan multimodal mobility services (e.g. park & ride services). The UC6 is devoted to traffic management and specifically on the exploitation of multi-source data and data analytics to assess the performance of C-ITS enabled traffic management scenarios. This use case will support TMCs to better plan their adopted strategies and incorporate vehicle connectivity technologies in their operational procedures and processes.

Moreover, the process mentioned in the first paragraph led to the identification of 37 requirements for the nuMIDAS toolkit. The vast majority of them are functional requirements and provide a description of what the toolkit should be capable of doing to fulfil the objective set in the analysis of each use case. These requirements are associated with one or more use cases or even with the user interface of the toolkit's dashboard. Finally, a few non-functional requirements have been identified related with security, computational efficiency, and the need to account for network sizes of large metropolitan areas.

The current challenge for our team is to develop the advanced methods and tools that will address these use cases. To this end, the outputs of this deliverable will feed, among others, the work planned to be carried out in the context of WP3 (advanced methods and tools formulation). Within the course of the aforementioned WP, the current use cases will be studied in detail and adapted (if deemed necessary) to better respond to emerging needs or new dimensions that will be uncovered during the development, functional verification, or validation process.

8 References

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