Deliverable 4.3

Overview of dynamic mobility operations use cases

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Table of contents

List of figures

List of tables

Acronyms

ANPR	Automated Number Plate Recognition
DSS	Decision Support System
EC	European Commission
GA	Grant agreement
KPI	Key Performance Indicator
MaaS	Mobility-as-a-service
NIL	Nuclei di Identità Locale (Local Identity Neighbourhoods)
nuMIDAS	New Mobility Data and Solutions Toolkit
OD	Origin/Destination
WP	Work package
UC	Use Case

1 Executive summary

Deliverable 4.3 aims to gather information about Use Case 1 (Pre-planning of shared mobility service) and Use Case 2(Operative areas analysis shared mobility), their technical characteristics (input data, database structure) and the description and interpretation of the results.

In particular, UC1 aims to solve a problem of optimising the size of the sharing fleet, analysing only one mode of transport at a time. Specifically, the algorithm seeks the optimal solution that takes into account, on the one hand, the municipal administration's need to satisfy user demand and, on the other hand, the service operator's desire to make a profit.

UC2, instead, focuses on defining operational areas for the different transport modes of sharing mobility. Specifically, the algorithm provides several alternatives of operational areas, each of which has different associated KPIs. In this way, the public decision-maker can assess which of the proposed alternatives is the one that most optimises user demand coverage and profit for the service operators.

In particular, for each use case the problems encountered by the pilot city of Milan on the issue of mobility sharing and the objectives achieved by the algorithms developed for each of the two use cases were reported. In addition, a technical analysis was also conducted on the types of data that were used for the co-design of the tools.

Moreover, the results of several scenarios, some of them deliberately extreme, were also reported in order to describe and validate the behaviour of the tools with very different starting conditions. Finally, an interpretation of these results was also provided.

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 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 its is being developed by a European Consortium, composed of 9 partners from 6 countries: Belgium, Czech Republic, Greece, Italy, The Netherlands, and Spain.

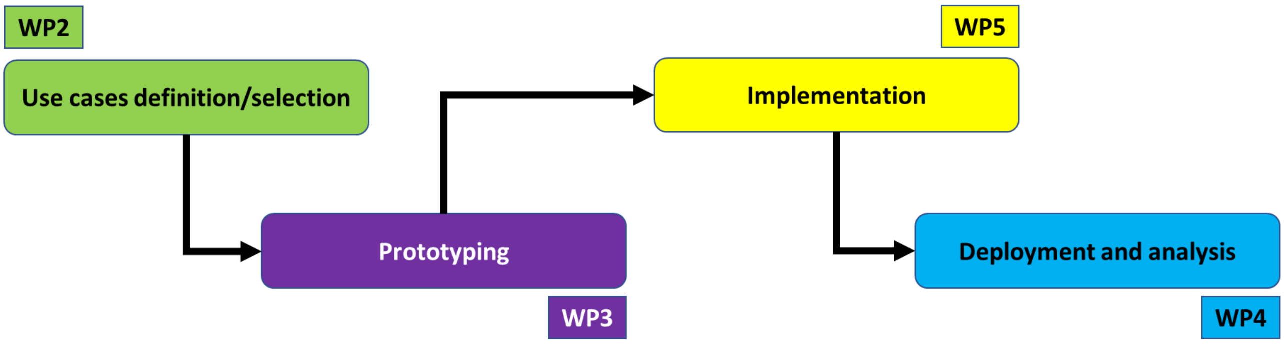
The project builds on a distributed selection of case studies in pilot cities to provide a geographic coverage of the EU. The four pilot cities are: Barcelona (Spain), Milan (Italy), Leuven (Belgium), and Thessaloniki (Greece).

2.2 Purpose of this document

A critical expectation for this project was to be able to draw conclusions and formulate recommendations that are relevant across the whole EU, and not just for selected locations. To this end, this project built on a distributed selection of case studies in pilot cities to provide a geographic coverage of the EU, with each pilot city an active partner in the consortium as well as being accompanied by a local core partner:

- The city of Barcelona (AMB INFORMACIO) in Spain, supported by FACTUAL.
- The municipality of Milano (AMAT) in Italy, supported by POLIEDRA.
- The city of Leuven (LEUVEN) in Belgium, supported by TML.

The use cases that were considered by each of these pilot cities were used to further validate our research, i.e. we used the proposed new variables and KPIs from WP2 as well as the methods and tools from WP3. The toolkit (in the form of a dashboard) from WP5 was used to incorporate the previously defined methods and tools, and thus providing researchers, planners, and policy makers a visualisation of the results as highlighted in their case studies.



The six selected uses cases were prototyped in WP3, and finally ended up being implemented in WP5 and deployed in WP4. Whereas WP3 worked with more proof-of-concept data, the results from working with the actual data from the pilot cities in WP5 is reported in the set of WP4 deliverables:

- **D4.1: Overview of traffic operations use cases**
  - UC4 (Planning for parking)
  - UC5 (Inflows and outflows in a metropolitan area)
  - UC6 (Assessment of traffic management scenarios)
- **D4.2: Overview of emissions and air quality use cases**
  - UC3 (Air quality analysis and forecasting)
- **D4.3: Overview of dynamic mobility operations use cases**
  - UC1 (Pre-planning of shared mobility services)
  - UC2 (Operative areas analysis)

The aim of the current Deliverable D4.3 is to describe in detail the backgrounds, setups, deployments, and results for Use Case 1 and Use Case 2 concerning the shared mobility service in the city of Milan. Specifically, as well as reporting the starting challenges and needs that the city of Milan through its partner AMAT, expressed at the beginning and during the project, for the two use cases concerning shared mobility, highlighting the following information:

- the descriptions of the input data used in the co-design phase of the algorithms,
- the structure of the database,
- the explanation of how the tool can be used in the dashboard through the outline of input data and output data,
- the depiction of some of the test simulations done to calibrate and validate the algorithm in an iterative manner.

2.3 Structure of this document

This deliverable is divided, ideally, into four parts:

- The first part (chapter n°3) with a description of the iterative process that led to the definition of the tools, and especially those with a focus on mobility sharing. In particular, reference is made to use case 1 and use case 2 which have Milan, Italy, as their pilot city.
- The second and third parts (chapter n°4 and chapter n°5) are respectively dedicated to the detailed description of UC1 and UC2, also through the analysis of the algorithms that were co-constructed to solve the challenges posed by the city of Milan at the beginning of the project.
- The last part (chapter n°6) of the deliverable contains the conclusions and considerations for the two use cases analysed.

3 Definition of Use Case 1 and Use Case 2

The two use cases on the city of Milan start from the Municipality's need to make the sharing services more efficient in both their planning and operational phases. In particular, two issues emerged during the iteration and the discussion among the project partners. Moreover, the first issue regards the enhancement of the tendering process by identifying the optimal value of the fleet for each mode of shared transport. Specifically, the municipality of Milan, in order to identify the optimal value of the fleet, has to take into account two factors: on the one hand satisfying the transport demand for that specific mode (car-sharing, bike-sharing, moped, kick-scooters), on the other hand ensuring the service operators the right revenues that make the activity profitable. Regarding the second issue, it is the operational areas of each shared transport vehicle that are being redefined. In fact, the objective of the Milan municipality is to redesign the operating areas so that more users can have access to the services even in those areas of low demand but, at the same time, guaranteeing service operators revenues to support their activities.

As reported in Deliverable 2.2 (Mylonas et al., 2021), the two use cases that are the subject of this deliverable were co-designed through an iterative process that began with a discussion among the partners of the problems and issues to be addressed. In addition, the discussion was also enriched by a careful analysis of the state of the art based on past and running projects, scientific papers and existing implementations regarding the methods and the tools that support policy makers, transportation planners/researchers in the sharing mobility planning and operational phase (Pribyl et al. 2021).

At a later time, a questionnaire was sent to city representatives in order to understand what the requirements were, in terms of functionality, from the city. Specifically, questions were asked about: the object of the tools, the criticalities, and challenges that the city of Milan has to face concerning sharing mobility and finally, how the tools of the nuMIDAS project could help decision makers to solve the issues. Moreover, with a view to the transferability of the tools (D5.4), a survey was conducted involving mobility experts outside the project partners, in which they were asked to identify what the biggest challenges for future mobility were. In addition, the data held by the Municipality of Milan were also carefully and thoroughly evaluated in order to develop algorithms that takes into account information already present in the municipal databases.

Once all the information, data, requirements and understanding of the challenges for the city of Milan regarding the topic of sustainable mobility had been gathered, first drafts of the two algorithms related to the use cases was realised using the Python programming language. In particular, the development of these algorithms followed a co-design process. Specifically, the codes in Python were also written through continuous iteration and collaboration between the project partners and the and representatives of the city of Milan (AMAT).

Finally, also with reference to the co-design process by which the tools were created, calibration and validation analyses were conducted.

4 Pre-planning of shared mobility services (use case 1)

4.1 Description

The focus of the first tool of nuMIDAS toolkit (related to UC1) is on mobility sharing and in particular on all modes of shared transport in the city of Milan:

- Car sharing (both free-floating and station-based modes)
- Bike sharing (both free-floating and station-based modes)
- Moped sharing
- Kick-scooters sharing.

Following, the use case approach described in deliverable D2.2 (Mylonas et al. 2021), the actors/users (namely the user of the tool) who are involved in this UC1 are mainly policy makers and the transport planners that support them and service operators. However, even if they do not use the tool, the end users (e.g., citizens, city users, travellers, etc.) of mobility sharing, namely the users of the services, are also the object of the analysis.

Specifically, the algorithm solves an optimisation problem, concerning the size of the fleet for each mode of shared transport, thus constituting a valuable tool for decision support, and can be used during the strategic and tactical phase of the use case (Pribyl et al. 2021).

From a computational point of view, the estimation of daily demand profile is derived from the trip data, the expected daily demand, and the transport mode to be analysed. The demand profile can take two forms: the first is that of a constant straight line throughout the day, the second, closer to reality, is a profile with demand peaks. The next step is service queue estimation. This evaluation is derived from the service type data (free-floating or station-based), the average trip duration and the minimum and maximum fleet values to be investigated. The two previous estimates combined together provide the served demand from which the coverage demand can be calculated. Once the covered demand is obtained and the costs and earnings per minute per vehicle are known, it is possible to calculate the estimated profit the service operator makes. Finally, from the expected profit, taking the covered demand is obtained the optimal fleet, which is also affected by the weight given to the two actors in the system, namely the service operators and the policy makers.

In the end, the tool is designed to be used in an iterative manner, exploring the different solutions presented to the decision maker who modifies the input parameters from time to time.

4.2 Input data

Description of the data used for the co-designing phase of the algorithm (e.g., description of shapefile, O/D matrix, NIL)

- Shapefile NIL: Nuclei d'Identità Locale (Local Identity Neighbourhoods) represent areas that can be defined as neighbourhoods of Milan, in which it is possible to recognise historic and planned neighbourhoods, with different characteristics from one another. They are introduced by the PGT (Piano di Governo del Territorio - Territorial Government Plan) as a set of areas, connected by infrastructures and services for mobility, green areas. In addition, they express territorial phenomena representative of local dynamism, and collect data from heterogeneous registry and census sources, related through processing with geographic-territorial data. However, for greater accuracy, subdivisions of the NILs were used for a total of approximately 370 zones.
- OD Matrix: In particular, the data represents the O/D matrix of trips by reason and mode, estimated using a transport model and calibrated in relation to the morning rush hour (08:00-09:00) of an average weekday in 2018.
- Following is the description of the acronyms contained in the fields of the table:
    - I - Origin (see shape file ZONING, field URBAN_08_2)
    - J - Destination (see shape file ZONING, field URBAN_08_2)
    - CASA_ - trips made by reason of return home
    - LAV_ - trips made for work reason
    - STUD_ -trips made for study reason
    - AFF_ - journeys made for business reasons
    - ALT_ - trips made for reason other
    - SHOP_ - trips made for shopping reason
    - CAR - trips made by car mode
    - TPL - trips made by public transport mode (collective)
    - MOTORCYCLE - trips made by motorbike or scooter mode
    - PIBIC - trips made by "soft" mode (walking, cycling, scooter, etc.)
    - PNR - trips made by Park & Ride interchange (car and train, car, and subway).
- Data regarding the four transport (car, moped, bike, kick scooter) mode analysed. Specifically:
    - Typology of service (station based or free floating)
    - How many vehicles
    - Average speed.

4.3 Setup and deployment

This section presents the database structure for UC1. This structure is mainly composed of two databases: the first one collects data on the trips made per individual mode of shared transport, divided by day and time slot, while the second one shows the geometric characteristics of the areas into which the city has been divided.

Table 1: Time series of hourly trips of existing sharing services per mode.

Title	Fields	Data type
Time series of hourly trips of existing sharing services per mode	Mode Datetime Trips	bigint text double precision

As can be seen from the table, there are three fields that make up the database: the first is the mode of transport (car, bicycle, scooter, moped), the other column is the data on the day and time slot in which the trips were made, while the last column provides information on how many trips were made per mode of transport in that time slot.

Table 2: City Geo data.

Title	Fields	Data type
City Geo data	Id Id_nil Nil Shape_leng Shape_area Data Geom	bigint bigint text double precision double precision bigint text

The database provides information on the division of the city into different zones, each with its own geometric characteristics (area, length of perimeter, etc.).

4.4 Usage guidelines

In order to be able to use the algorithm, the user of the tool has to provide data and information mainly concerning the characteristics of the mode of shared transport (average trip duration, average number of trips per day, cost of vehicle use). In addition, the user is asked to make certain choices such as the allocation of decision weights, the minimum and maximum number of means of transport to be available, and the algorithm's use of the demand for the analysed mode of transport, which can be either the average daily demand or the hourly demand.

Specifically, the following data are required for the algorithm to work properly:

- Selection of the type of mode to be analysed (bike, moped, kick-scooter, or car-sharing): it is the mode of transport used in the simulations.
- Selection of the type of service to be analysed (station-based or free-floating): this data can only concern bike sharing and car sharing as mopeds and kick scooters are always in free-floating mode.
- Expected daily demand (trips/day): this data concerns the average value of the daily trips made with the selected mode of transport.
- Size of the area of interest (in km^2): It is the territorial extension in which the service is active.
- Operating costs per vehicle per minute (in Euros): are the expenses which are related to the maintenance of the car (parking costs, insurance, car maintenance costs). The costs incurred by the provider per minute is an average daily cost, which therefore takes into account both the minutes when the vehicle is in operation and the minutes when it is stationary and parked. However, the actual value of the cost may be difficult to find as the sharing providers are often unwilling to provide this data. Therefore, this input data must be estimated. A reliable estimate is to consider this cost as a percentage of the revenue obtained per minute of rental.
- Expected revenues per minute of rent (in Euros): these are the earnings that the operator of the service obtains and derives from the payment by the user of the rental rates. The value could be the cost the user pays per minute of rental.
- Average user walking speed(km/h): it is the average speed of a pedestrian. In this case, the default value is 3 km/h. This is a prefilled field.
- Mean trip duration (in minutes): it is the average of the vehicle usage time of a certain mode of transport.
- Weighting factors assigned to service operator’s and end society's perspectives: the weights are the coefficients that measure the relative importance end-users and operators. The sum of the two weights always equals 1.
- Minimum and maximum value of the fleet size: it is the lowest and highest number of vehicles to be considered as the operational fleet.
- Elastic demand: through this input, the system user decides whether to use a uniformly distributed demand throughout the day or to use the real demand curve
- Hourly demand defined by user (in units): This parameter is to be changed if and only if the user decides to use the actual demand curve. Through this input, the user can decide to modify the demand peaks, flattening or emphasising them, but always keeping the daily demand constant
- Profit higher than this value (in Euros): it is the profit threshold above which the simulation is stopped. This input parameter was introduced to reduce the calculation time of the algorithm.

At the end of the calculation, the tool has the following parameters as output:

- Demand coverage: It is the percentage of the demand that is covered by the service conducted by the optimal fleet size.
- Average walking time: It is the time that it takes a user to reach the closest selected sharing vehicle.
- Average waiting time: It is the time that is needed by the user to arrive at the position of the vehicle.
- Optimal fleet size: Is the combination of the optimal fleer size end users’ perspective and optimal fleet size operators’ perspective. It depends on the weight that is assigned during the creation of the scenario.
- Optimal fleet size from end users' perspective: The number stands for the optimal fleet size in order to have the lowest value both for average walking and waiting time.
- Optimal fleet size operator perspective: It represents the optimal number of vehicles that maximise the providers’ profits.
- Profit service providers: It is the daily profit for a shared mobility provider. This value depends on both the demand and the optimal fleet size.

4.5 Results

This section presents some results of simulations conducted to verify the behaviour of the algorithm when certain input parameters changed.
In particular, scenarios that have been calculated through the dashboard are shown. Specifically, it was chosen to use input parameters representing 'extreme' situations. Below are the simulations conducted:

- Scenario 1: High demand low fleet
- Scenario 2: Low demand high fleet
- Scenario 3: Weight factor significantly in favour of the society
- Scenario 4: Weight significantly in favour of the service provider.

It is specified that scenarios 3 and 4 will have the same input data except, precisely, for the weight factors of the two actors involved in the use case.

For each scenario, the input parameters are defined in a table and then the results are also discussed through some screenshots from the dashboard.

Table 3: Scenario 1.

Input	**Value**
Mode type	Bike
Service type	Free floating
Expected Daily Demand	4715
Size of the area of interest (in km2)	14
Operating costs per vehicle per minute (in Euros)	0,02
Expected revenues per minute of rent (in Euros)	0,22
Average user walking speed(km/h)	3
Mean trip duration (in minutes)	12
Weighting factors assigned to service operator's perspective	0,5
Weighting factors assigned to society's perspective	0,5
Minimum value of the fleet size	50
Maximum value of the fleet size	1500
Elastic demand	0
Hourly demand defined by user (in units)	0
Profit higher than this value (in Euros)	0

The following figures show the simulation results.

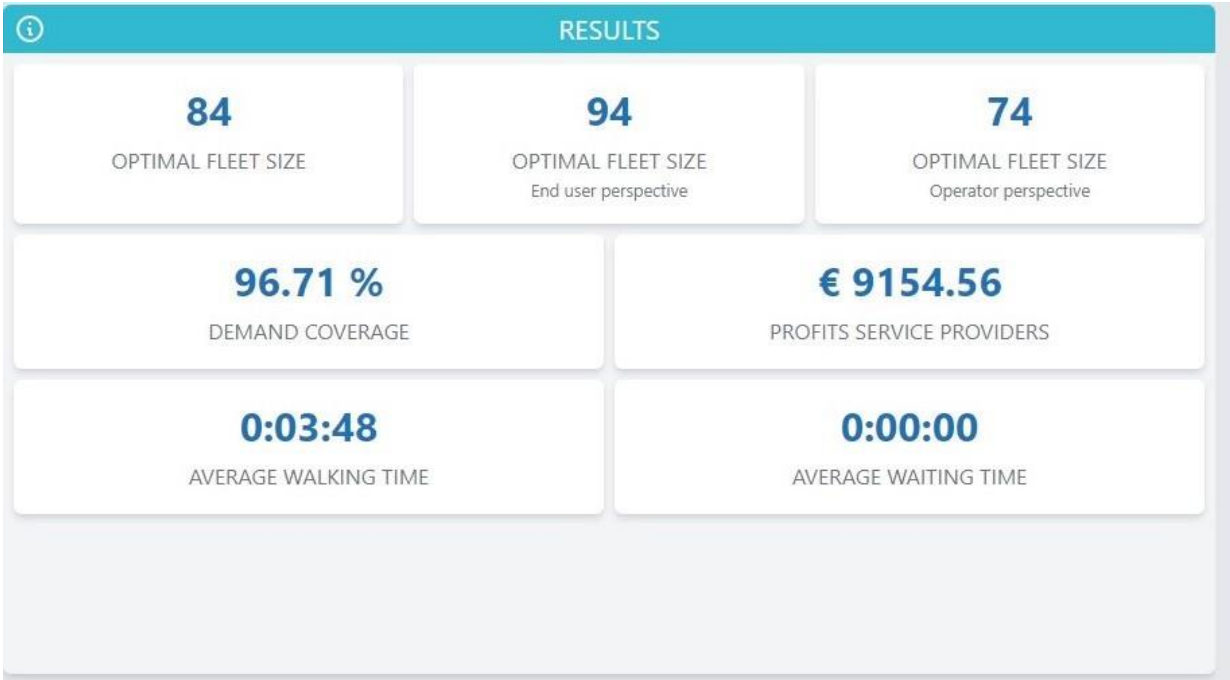


Figure 1: Scenario 1 results (first part).

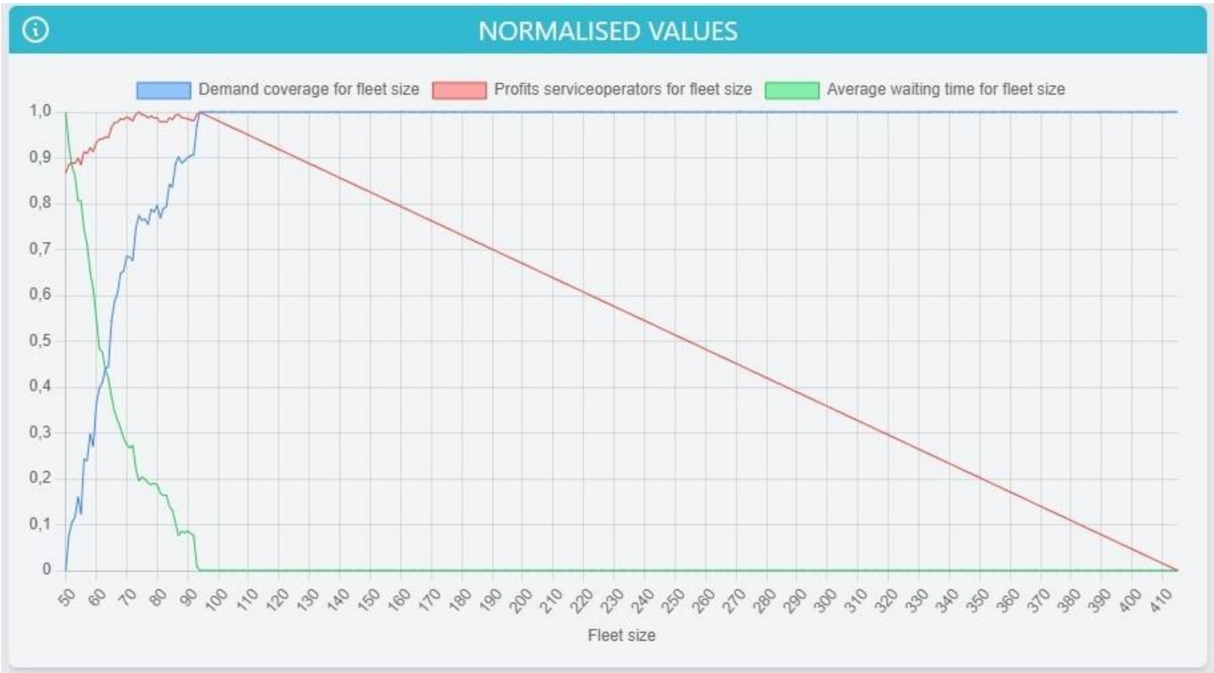


Figure 2: Scenario 1 results (second part).

As can be seen from both the results and the graphs, for this scenario, the optimal fleet is 84 free-floating bicycles. In addition, demand is about 97% covered, outlining a very good coverage of the service for the user segment. The average waiting time is 0 because the system recognises that a bicycle is always available when the user searches for a means of transport. The average walking time is within an acceptable value for which the user may choose to use the bicycle for his or her commute. A higher value would invalidate the use of bike sharing as it would be close to the mean trip duration. However, the profits for the service operator seem to be overestimated. In fact, the value only takes into account the phase of the business model that is strictly related to transport activities such as the costs borne by the vehicle operator, while other factors (i.e. congestion charge fees, parking costs, etc.) were not taken into account.

Table 4: Scenario 2.

Input	**Value**
Mode type	Bike
Service type	Free floating
Expected Daily Demand	2000
Size of the area of interest (in km2)	14
Operating costs per vehicle per minute (in Euros)	0,02
Expected revenues per minute of rent (in Euros)	0,22
Average user walking speed(km/h)	3
Mean trip duration (in minutes)	12
Weighting factors assigned to service operator’s perspective	0,5
Weighting factors assigned to society's perspective	0,5
Minimum value of the fleet size	1500
Maximum value of the fleet size	3000
Elastic demand	0
Hourly demand defined by user (in units)	0
Profit higher than this value (in Euros)	0

The following figures show the simulation results.

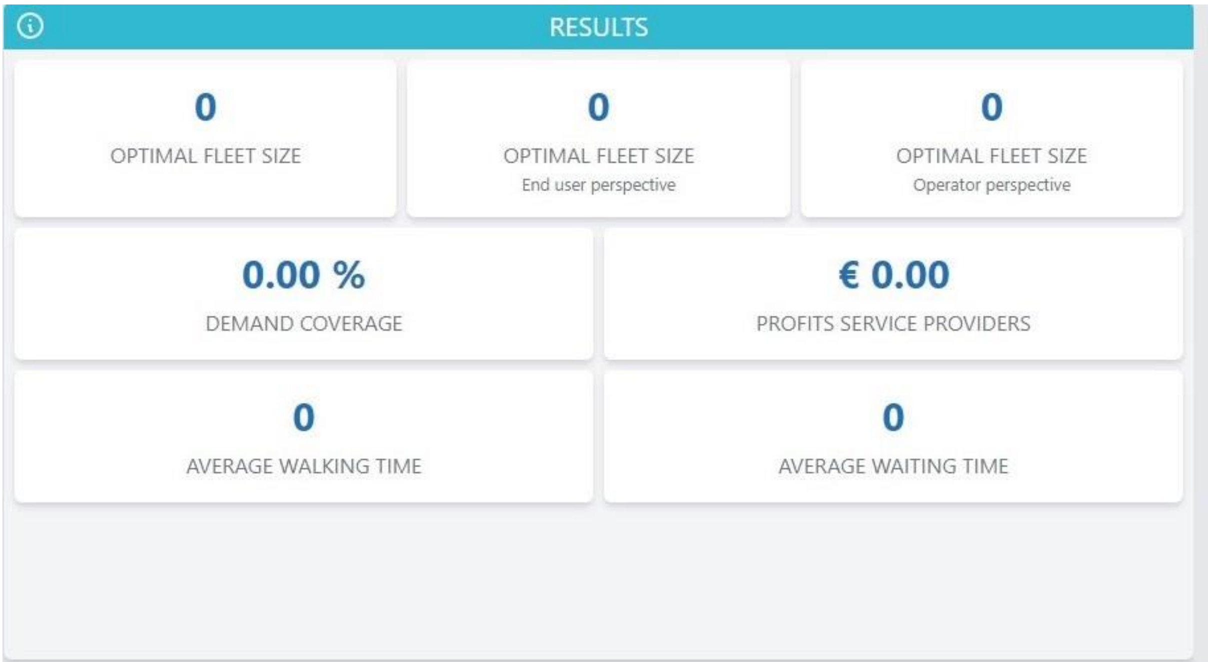


Figure 3: Scenario 2 results (first part).

Figure 4: Scenario 2 results (second part).

The results of this scenario are all 0 since demand is lower than the number of bikes installed by the operator, the bike-sharing service has negative profits and therefore the algorithm blocks the calculation and gives the 'null' scenario as the result.

Table 5: Scenario 3.

Input	**Value**
Mode type	Bike
Service type	Free floating
Expected Daily Demand	4715
Size of the area of interest (in km2)	14
Operating costs per vehicle per minute (in Euros)	0,02
Expected revenues per minute of rent (in Euros)	0,22
Average user walking speed(km/h)	3
Mean trip duration (in minutes)	12
Weighting factors assigned to service operator’s perspective	0,1
Weighting factors assigned to society's perspective	0,9
Minimum value of the fleet size	50
Maximum value of the fleet size	1500
Elastic demand	0
Hourly demand defined by user (in units)	0
Profit higher than this value (in Euros)	0

The following figures show the simulation results.

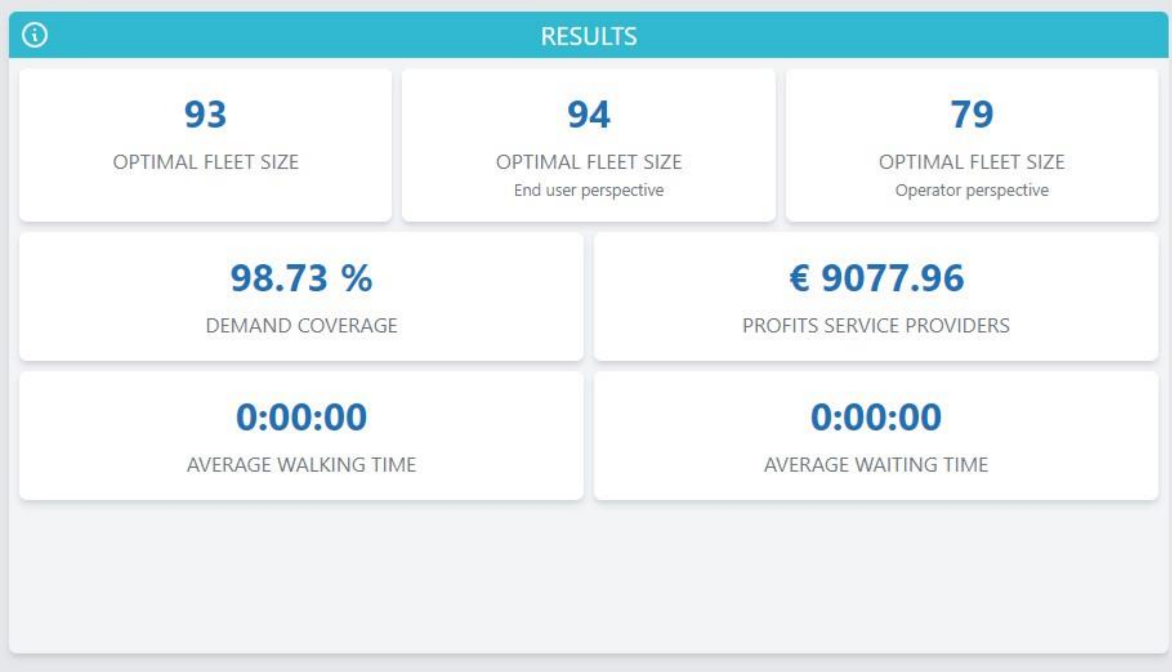


Figure 5: Scenario 3 (first part).

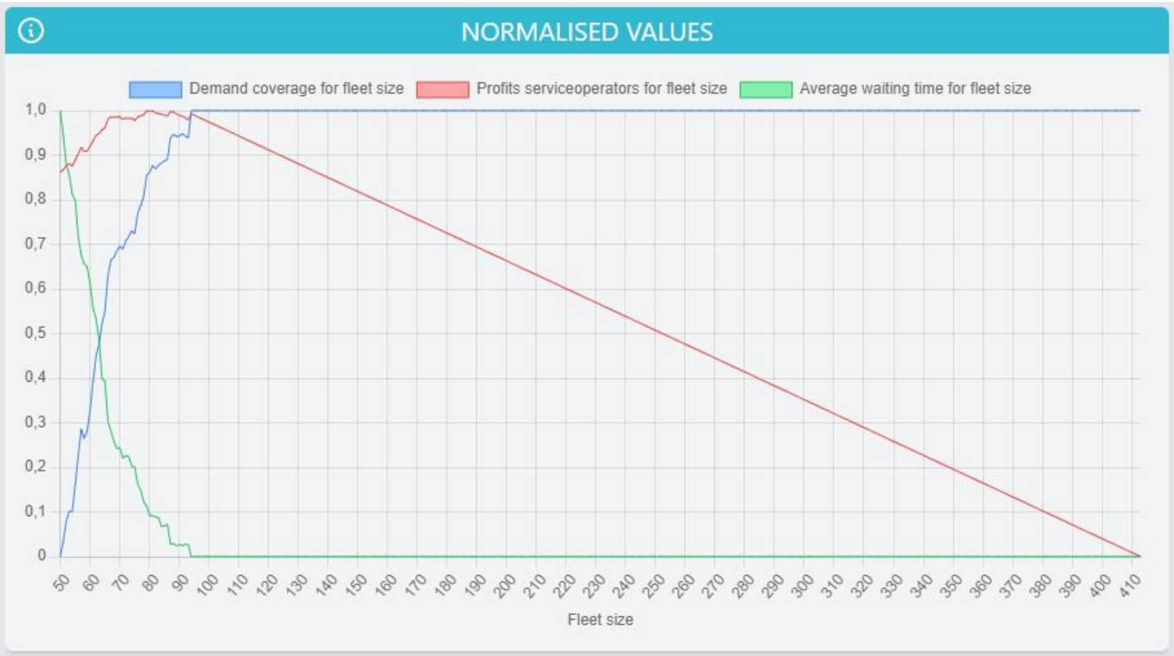


Figure 6: Scenario 3 (second part).

For this scenario, it started from the same inputs as in scenario 1, but changed the factors of the weights. Scenario 3, considers a net imbalance for 'society'. In fact, looking at the results, the optimal fleet value (93) is very close to the optimal fleet value for the end user (94), indicating how the algorithm took into account that the preponderant objective for this simulation is to satisfy demand at the expense of the operator's profit. As a result, compared to scenario 1, demand coverage is greater while profits are slightly lower (the same reasoning applies to profits as for scenario 1). However, the value of the average walking time appears to be underestimated as one does not always have a vehicle available without having to walk a short distance anyway.

Table 6: Scenario 4.

Input	**Value**
Mode type	Bike
Service type	Free floating
Expected Daily Demand	4715
Size of the area of interest (in km2)	14
Operating costs per vehicle per minute (in Euros)	0,02
Expected revenues per minute of rent (in Euros)	0,22
Average user walking speed(km/h)	3
Mean trip duration (in minutes)	12
Weighting factors assigned to service operator’s perspective	0,9
Weighting factors assigned to society's perspective	0,1
Minimum value of the fleet size	50
Maximum value of the fleet size	1500
Elastic demand	0
Hourly demand defined by user (in units)	0
Profit higher than this value (in Euros)	0

The following figures show the simulation results.

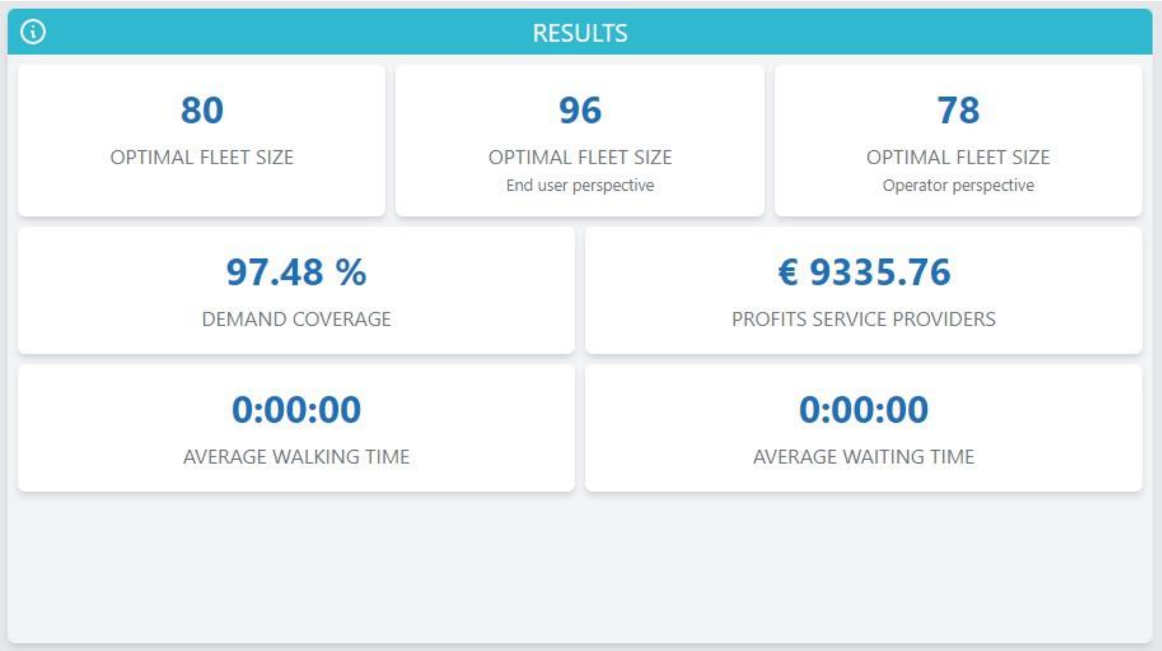


Figure 7: Scenario 4 results (first part).

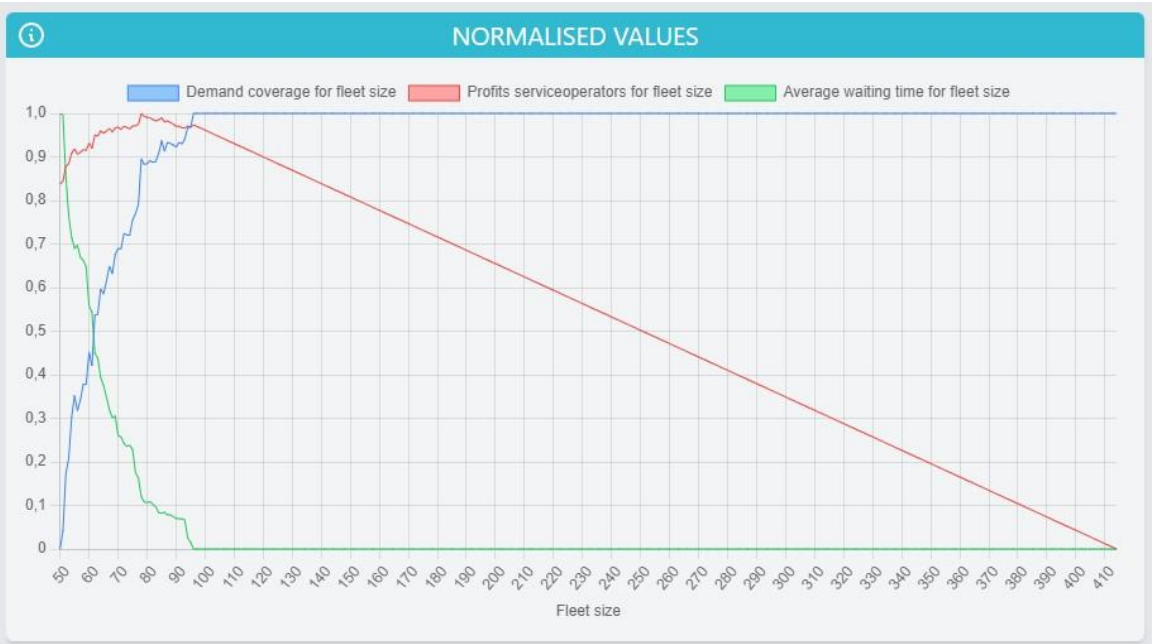


Figure 8: Scenario 4 results (second part).

For scenario 4, the scenario used for scenario 1 and scenario 3 was also taken as the base scenario, but the weight factors were changed. Specifically, in this case it is the service operator who benefits from a greater unbalance. This imbalance is visible both in the value of the optimal fleet (80), which is very close to the operator's optimal fleet value (78), and in the value of profits, which is higher than both scenario 1 and scenario 3. This decrease in vehicles results in a slight decrease in the demand covered by the service. All the considerations made for profits and average walking time in the comments to scenarios 1 and 3 remain valid.

5 Operative areas analysis shared mobility (use case 2)

5.1 Description

The main objective of the UC2 tool is to redefine the operational areas of sharing services in the city of Milan. As already seen in section 3, the challenge that the city of Milan has is that of a substantial overlap of operational areas in the city centre while in the various peripheral areas sharing services (of all transport modes) are often missing. With the aim of increasing the number of people who have access to services and reducing the use of private cars, UC2 and the related tool is intended to enable the decision maker to explore the expansion and redistribution of operational areas.
Like the previous tool, this tool is a decision support tool. In fact, the purpose of the tool is to help the decision maker explore the different areas, the evaluated areas, of the city to be included within a basic operational area, defined as the set of currently served areas. In this way, through an iterative approach, the decision maker can assess, on the basis of the KPIs provided by the tool, which and how many areas should be included within the operational area for each individual mode of shared transport.

Operationally, the algorithm, performs a clustering by trips per areas and create all possible combinations creates all possible combinations between the areas to be evaluated and the areas that are currently served. For each cell, it applies a simplified model of the UC1 algorithm in order to identify which fleet is optimal and which costs and profits for the service operator are technically and economically feasible.

The algorithm co-designed for this Use case has the task of supporting the decision maker in the exploration of possible new areas of operation, indicating the different KPIs emerging from the computational flow and directing the user (the decision maker) towards the optimal choice both for the service operator, in terms of profit, and for the end users who may have greater accessibility to the shared service.

5.2 Input data

- Resident Population by NIL: they are the census population figure for each NIL (local identity district) in Milan. However, for greater accuracy, subdivisions of the NILs were used for a total of approximately 370 zones.
- OD matrix by NIL: is the OD matrix for all the travels that have origin and destination from and in the same NIL and travels that have origin in one NIL and destination in another and vice versa. However, for greater accuracy, subdivisions of the NILs were used for a total of approximately 370 zones.
- Shapefile of the current served areas for:
    - Car sharing: The shape of the official operative area is called “centro abitato (town centre)”
    - Bike sharing: The whole area is composed by the two shapes on the folder “aree esterne (external areas)” and “centro abitato (town centre)”
    - Kickscooter sharing: The shape of the official operative area is called “micoperturacompleta (micro-coverage-complete)”
    - Moped Sharing: The shape of the official operative area is called “Perimetro 90_91 (90-91 circle, it is referred to the part of the city within the trolleybus circle).

5.3 Setup and deployment

In this section, the structure of the database is shown. In order to clearly describe the structure, for each file that makes up the database, the file name has been defined, what it refers to and what fields and data type make up the file. This information has been summarised in the following tables. In addition, a brief description of the contents of the files and the acronyms in them has been provided.

Table 7: Shapefile NIL with indication of areas currently served in the various mode.

Name	Title	Fields	Data type
"IT_MIL"."OASM_in_Mandatory_areas"	Shapefile NIL with indication of areas currently served in the various modes	"NEW" "URBAN_08_2" "Centroid_X" "Centroid_Y" bikeshar carshar kscooter moped	bigint bigint double precision double precision double precision double precision double precision double precision

The shapefile in table 7 contains data on the spatial geometries of the NILs together with indications of which areas of the city are already served for each transport mode analysed. In particular, the fields report the position of the centroids of the polygon of each NIL and also provide information regarding the presence or absence of the transport modes that are taken into account in this use case. In this way, the file returns a map, for each transport mode, of the current served areas (actual operative areas).

Table 8: Modal split according to Origin Destination distance.

Name	Title	Fields	Data type
"IT_MIL"."OASM_in_Modal_Split_Info"	Modal split according to Origin Destination distance	"Mode" "Avg_Km" "Modal_Split_Factor_Static_Fixed" "Max_Km" double precision "Min_Km" double precision	text double precision double precision double precision double precision

The file contains information regarding the modal split in relation to the distance between the trip origin point and the destination point. As regards fields, information is provided on average kilometres, maximum kilometres and minimum kilometres travelled for each mode of transport.
Modal_Split_Factor_Static_Fixed provides information on the modal split of trips made using shared vehicles. The data refer to individual trips and not to users of the service.

Table 9: Population by NIL.

Name	Title	Fields	Data type
"IT_MIL"."OASM_in_ZONING_3003_final"	Population by NIL	"NEW" "URBAN_08_2" "Centroid_X" "Centroid_Y" bikeshar carshar kscooter moped "POPOLAZION"	Bigint Bigint double precision double precision double precision double precision double precision double precision bigint

This file contains the same fields and the same information as shapefile shown in table 7, to which the field containing data on the population residing in each NIL has been added. This information is useful for estimating the potential demand for the use of sharing vehicles.

Table 10: Origin-Destination matrix split by mode and travel reason.

Name	Title	Fields	Data type
"IT_MIL"."OASM_in_final_od_final"	Origin-Destination matrix split by mode and travel reason	"I" "J" "CASA_AUTO" "CASA_TPL" "CASA_MOTO" "CASA_PIBIC" “CASA_PNR" “LAV_AUTO" "LAV_TPL" “LAV_MOTO" "LAV_PIBIC” "LAV_PNR" "STUD_AUTO" "STUD_TPL" "STUD_MOTO" "STUD_PIBIC" "STUD_PNR" "AFF_AUTO" "AFF_TPL" "AFF_MOTO" "AFF_PIBIC" "AFF_PNR" "ALT_AUTO" "ALT_TPL" "ALT_MOTO" "ALT_PIBIC"	bigint bigint double precision double precision double precision, double precision

		"ALT_PNR" "SHOP_AUTO" "SHOP_TPL" "SHOP_MOTO" "SHOP_PIBIC" "SHOP_PNR"	double precision double precision double precision double precision double precision double precision

The file contains the information from the origin-destination matrix, adding details of the mode of transport used to make these trips together with the reason for the trip. Below are explanations of the codes used within the database:

- I - Origin (see shape file ZONING, field URBAN_08_2)
- J - Destination (see shape file ZONING, field URBAN_08_2)
- CASA_ - trips made by reason of return home
- LAV_ - trips made for work reason
- STUD_ -trips made for study reason
- AFF_ - journeys made for business reasons
- ALT_ - trips made for reason other
- SHOP_ - trips made for shopping reason
- CAR - trips made by car mode
- TPL - trips made by public transport mode (collective)
- MOTO - trips made by motorbike or scooter mode
- PIBIC - trips made by "soft" mode (walking, cycling, scooter, etc.)
- PNR - trips made by Park & Ride interchange (car and train, car, and subway).

Table 11: Distance matrix.

Name	Title	Fields
"IT_MIL"."OASM _prein_skim_df"	Distance matrix	Origin 737 columns of “Distance from Origin to Destination”

Distance matrix

- Origin is the point of origin of the travel
- Destination is the point of destination of the travel
- Distance from Origin to Destination

Table 12: Hourly demand curve.

Name	Title	Fields	Data type

"IT_MIL"."OASM_in_Factors"	Hourly demand curve	“0" (hour of the day) "1" (percentage of demand)	bigint double precision

The file provides information on hourly demand for each mode of shared transport. In particular, this information shows in which time slots there are peaks in demand, relative to the daily hourly average, for which an adequate supply of services must be provided, and "negative" peaks relative to daily demand in which the supply of services exceeds demand.

5.4 Usage guidelines

In terms of inputs, UC2 takes up some of the inputs already seen during UC1 such as: the type of mode (bike, moped, kick-scooter, or car-sharing), the type of service (station-based or free-floating), the operating costs per vehicle per minute (in Euros), the expected revenues per minute of rent (in Euros), the weighting factors assigned to service operator’s and end-user's perspectives and the mean trip duration.

In addition to these parameters, the following must also be entered

- the initial served areas, which may be those already used by the service operators (historical data), or may be chosen manually,
- a set of additional areas to be mandatorily evaluated
- a set of areas to be excluded from the evaluation.

Consequently, all remaining areas are those under evaluation and the algorithm then provides the different alternatives.

Below is a list of all input data needed to start the UC2 simulations. For the parameters of this use case, which were also present in use case 1, the same considerations made in the section 4.4:

- Selection of the type of mode to be analysed (bike, moped, kick-scooter, or car-sharing)
- Selection of the type of service to be analysed (station-based or free-floating)
- Operating costs per vehicle per minute (in Euros)
- Expected revenues per minute of rent (in Euros)
- Mean trip duration (in minutes)
- Weighting factors assigned to service operator’s and end user's perspectives
- Currently served areas
- Areas to be evaluated
- Areas to be excluded.

As with the inputs, some outputs were also taken over from UC1 such as the costs and profits of the service operator. However, two additional outputs were added:

- Population covered: this represents the percentage of the population resident within the municipality of Milan which, with the addition of the new zones, falls within the new operational area of the service.
- List of all possible combinations of evaluated areas: it is a list of all possible combinations of currently served areas and evaluated areas. For each item in the list are the outputs seen before (service operators' costs and profits, population covered).

5.5 Results

The tool returns as output a file in .csv format in which there are six columns. Specifically:

- the first column represents the progressive number of possible combinations
- the second column shows the costs, in Euros, incurred by the service operator to the relevant operational area configuration
- the third column is the total accessibility calculated according to Hansen's Accessibility Model,
- the fourth column represents the percentage of the population, compared to the total population, which has access to the sharing service
- the fifth column reports the service operator's profits at the relative configuration of the operational area
- The sixth column the number of areas constituting a defined operational area.

	system_cost	total_accessibility	population_covered	systen_profit	number_of_served_areas
0	271,2	12,79869491	0,3217	1627,2	113
1	273,6	12,91019734	0,3239	1641,6	114
2	276	13,07360728	0,3271	1656	115
3	278,4	13,15520966	0,3301	1670,4	116
4	280,8	13,24216178	0,3338	1684,8	117
5	283,2	13,32904623	0,3394	1699,2	118
6	285,6	13,40270588	0,3417	1713,6	119
7	288	13,49784507	0,3456	1728	120
8	292,8	13,60249241	0,3496	1756,8	121
9	297,6	13,70197214	0,3513	1785,6	122
10	300	13,79994157	0,3555	1800	123
11	304,8	13,97691488	0,3603	1828,8	124
12	307,2	14,11443425	0,3651	1843,2	125
13	309,6	14,24266911	0,3674	1857,6	126
14	312	14,3442459	0,3711	1872	127
15	316,8	14,52611583	0,3745	1900,8	128
16	319,2	14,57936091	0,3776	1915,2	129

Figure 9: Example of UC2 results.

Below, some output images of some simulations conducted using the algorithm are shown. While the different shades of blue, from the darkest to the lightest, represent the areas to be served. Finally, the areas in grey, are those where the system does not consider the possibility of implementing the analysed sharing service.

Looking at the figure, it can be seen that the areas to be taken into mandatory consideration are those in the city centre. Once these areas have been set up and the simulation has started, the algorithm returns as 'first' areas to be considered, all but 2 areas in the first belt of the city centre. Furthermore, it can be seen that the areas in which the service can be implemented are, with few exceptions, all areas located in concentric belts that move away from the centre.

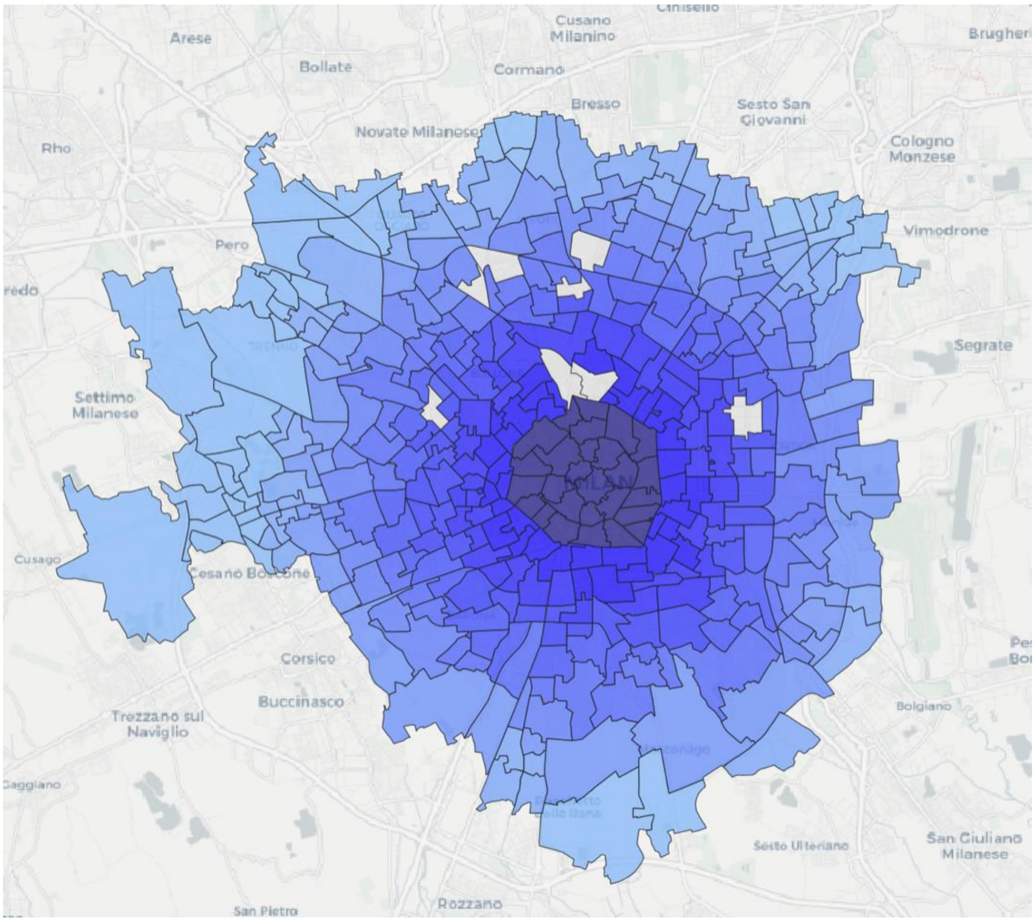


Figure 10: Scenario 1 results.

system_cost	total_accessibility	population_covered	systen_profit	number_of_served_areas
72	3,301137814	0,0573	432	27
158,4	7,173428364	0,1702	950,4	65
254,4	11,53952987	0,3007	1526,4	102
319,2	14,76118166	0,4089	1915,2	140
400,8	18,32542588	0,5387	2404,8	178
436,8	20,05751398	0,6308	2620,8	216
468	21,7065778	0,7286	2808	254
487,2	22,84104235	0,8177	2923,2	292
501,6	24,26740221	0,8993	3009,6	330
506,4	25,15570067	0,9727	3038,4	368

Figure 11: 10 scenarios from Scenario 1 results.

The numerical outputs of the simulation are collected in the table above. In particular, each row represents each colour gradation in which the areas were clustered. Specifically, the first row is the row of all the areas in the dark blue gradation (i.e. the one that must be evaluated) while the last row represents the algorithm's results for the light blue areas. Starting with a mandatory area in which to conduct the evaluation of 27 zones and as can be seen at the end of the simulation and also from a graphical point of view, out of a total of 376 zones into which the city of Milan has been divided, for the simulation conducted the sharing service can be implemented in 368 zones, covering 97% of the city's resident population.

In this other simulation, in addition to taking the city centre as the obligatory assessment area, other areas in the eastern part of the metropolis were also chosen (fig 12). The algorithm gives a completely different result: there are no longer the concentric bands seen in the figure, but the areas that are taken into account are those that lie between the two areas indicated as being compulsorily evaluated. Furthermore, it can be seen that a large part of the city's territory would be excluded from the possibility of implementing the analysed sharing service.

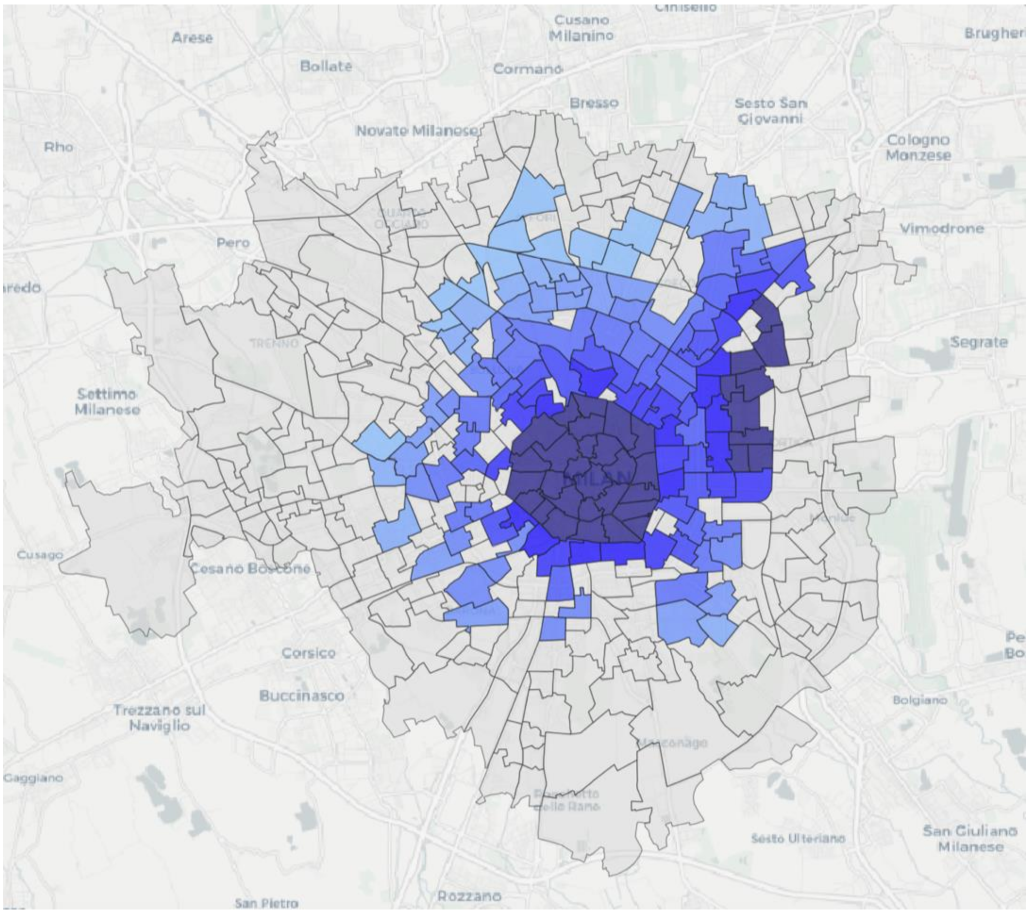


Figure 12: Scenario 2 results.

system_cost	total_accessibility	population_covered	systen_profit	number_of_served_areas
96	3,833704713	0,0883	576	36
132	5,183721027	0,1368	792	49
177,6	7,014051991	0,191	1065,6	62
216	8,683607393	0,2424	1296	75
268,8	11,61911356	0,2936	1612,8	88
319,2	13,35352222	0,3506	1915,2	102
348	14,48031558	0,3896	2088	115
384	15,72390874	0,441	2304	128
415,2	16,71595887	0,4838	2491,2	141
432	17,62107739	0,5229	2592	152

Figure 13: 10 scenarios from Scenario 2 results.

In this simulation, the starting areas in which the evaluation must be conducted are 36. However, once the algorithm has calculated all outputs, it suggests implementing the service in at most 152 zones, covering slightly more than half (52%) of the resident population in the city of Milan.

Below are some screenshots of the UC2 interface in the dashboard. In particular, the figure shows the 'create scenario' section in which the user enters input data.

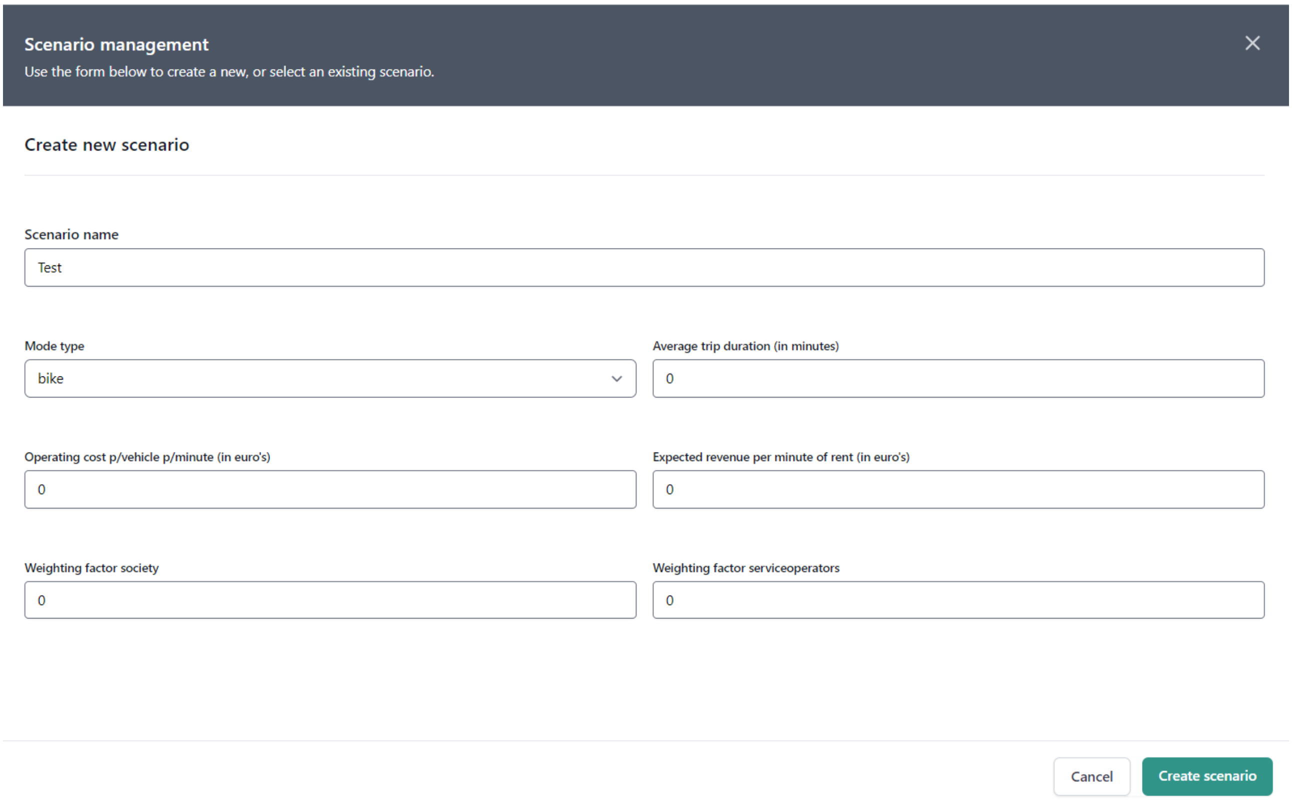


Figure 14: Create scenario section.

Once the data has been entered and the ‘Create scenario' button has been pressed, the user must return to the home page of the section, press the 'edit' button next to the created scenario. In this way, a map appears in edit mode. In this map, where the current served zones are shown in yellow, the user can decide whether to include a zone, exclude an already selected zone, or reset the zone to its starting value.

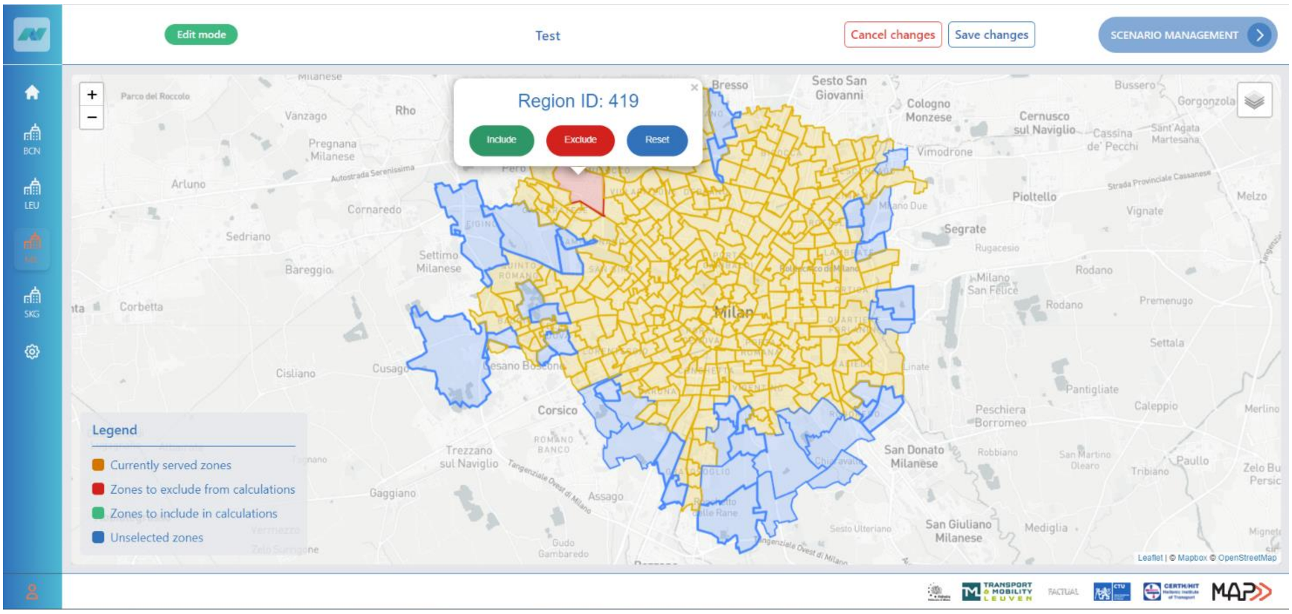
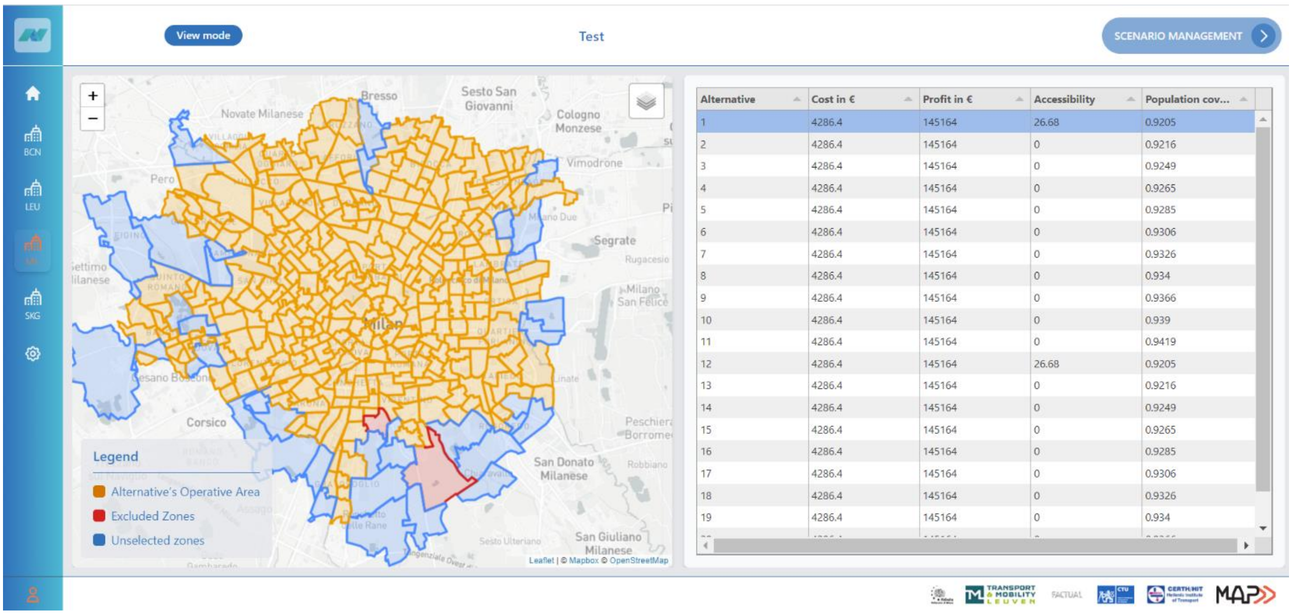


Figure 15: Edit mode.

After selecting the areas to be excluded, included, or reset, the user returns to the create scenario section in order to launch the simulation via the 'run' button.

At the end of the simulation is complete, the dashboard returns two main results: a map and a table with the KPIs calculated by the algorithm. Each row corresponds to a different alternative that is displayed each time on the map, allowing the decision maker to compare the different results.



Alternative	Cost in €	Profit in €	Accessibility	Population cov...
1	4286.4	145164	26.68	0.9205
2	4286.4	145164	0	0.9216
3	4286.4	145164	0	0.9249
4	4286.4	145164	0	0.9265
5	4286.4	145164	0	0.9285
6	4286.4	145164	0	0.9306
7	4286.4	145164	0	0.9326
8	4286.4	145164	0	0.934
9	4286.4	145164	0	0.9366
10	4286.4	145164	0	0.939
11	4286.4	145164	0	0.9419
12	4286.4	145164	26.68	0.9205
13	4286.4	145164	0	0.9216
14	4286.4	145164	0	0.9249
15	4286.4	145164	0	0.9265
16	4286.4	145164	0	0.9285
17	4286.4	145164	0	0.9306
18	4286.4	145164	0	0.9326
19	4286.4	145164	0	0.934

Figure 16: Results of the simulation.

In conclusion, Use Case 2 does not provide a single solution, but a set of solutions which can be evaluated both individually and as a whole and which are intended to support the public decision-maker in his/her choice and in his/her decisions.

6 Conclusions

As could be seen in the dedicated paragraphs, both algorithms developed for the use cases are essentially decision support tools. For this reason, they do not calculate a defined solution, but provide a set of alternatives, which can be compared with each other and which are able to support the decision maker in his or her choices concerning the sharing mobility sector.

Moreover, for UC1, user and operator have opposite interactions and it is possible to highlight that the trend of the output curves depends on the adaptation of user’s behaviour. In particular, the user has to accept that the number of the cars is lower than its optimum (end user's optimum) because the service operator, in order to continue to provide the service, he/she must be able to make a profit. For this reason, for high fleet sizes that enable coverage of 100% demand covered, the profit of the service operator becomes negative, making the provision of the service itself not economically viable.

In general, the same considerations apply to UC2 (which in fact replicates a simplified form of UC1 for each examined zone). In this case, the user must be aware that having the sharing service active in all zones of the city would not allow the economic operator to sustain its business. For this reason, the number of areas must be appropriate so that a good percentage of the population can be served by the sharing service and, at the same time, the service operators can earn enough to guarantee economic viability.

7 References

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Pribyl, O., Pereira, A. M., Hyksova, M., …. Carlier, K., Ons, B. (2021). State-of-the-art assessment. Deliverable 2.1 of the nuMIDAS project (H2020). https://numidas.eu/index.php/project-deliverables/