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nuMIDAS: Addressing new mobility policymaking challenges

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Abstract

The mobility ecosystem is rapidly evolving: new ways of data generation, collection and storage evolve with new forms of mobility and techniques.
Integrating these disruptive technologies into planning, decision making, and policymaking is a huge challenge. nuMIDAS (New Mobility Data and Solutions Toolkit) is an H2020 project, aiming to recognize new and emerging mobility trends, and identify new concepts and variables. nuMIDAS creates a tangible toolkit to support governments throughout Europe with a comprehensive approach regarding what datasets, methodologies, tools, and models are required or adapted. For the city of Milan, the policymakers require a tool for pre-planning of shared mobility services. The consortium is designing and developing a replicable and scalable application that processes available data and produces the output required by Milan city mobility planners.

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1. Introduction

The mobility ecosystem is on the edge of a new era. This ecosystem appears within cities and regions and will have effects on the public space, the environment, the inclusiveness of society, etc. It will thereby affect the liveability of cities and regions. New ways of data generation, collection and storage evolve with new forms of mobility and techniques.

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As such, (big) data generation analysis techniques like machine learning become more paramount and give more insight into the mobility needs of citizens and the performance and impact of (new) mobility solutions.

Integrating these disruptive solutions and technologies into coherent planning, decision making, and policymaking for mobility is a huge challenge at current. The nuMIDAS project creates a tangible and readily available toolkit to support local governments and bridges this gap by providing a comprehensive approach regarding what datasets, methodologies, tools, and models are required and which existing ones can be adapted. Moreover, nuMIDAS makes policy decisions measurable and quantifiable, and impact assessments more tangible and directly usable. By applying research and implementing the tools in pilot cities with varying problems and characteristics, wider applicability across Europe is guaranteed. 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, the Czech Republic, Greece, Italy, The Netherlands, and Spain. The project builds on a distributed selection of use cases in the following four pilot cities to provide geographic coverage of the EU: Barcelona (Spain), Milan (Italy), Leuven (Belgium), and Thessaloniki (Greece). For each use case, advanced methods and tools are iteratively developed in close collaboration with project partners and the related governmental organizations, taking into account the state-of-the-art approach for the smart mobility domain in question. One of the Milan use cases will be described in more detail in this paper. User story development combined with usability studies is used to guarantee a functional and usable tool.

The ultimate goal is to develop easily modifiable tools available in a single toolkit to maximize usability in Europe. To make this easy, transferability guidelines will be developed.

2. The new mobility data and solutions toolkit

2.1. Scope of the toolkit

The prototype development approach is driven by (market) research, quantitative modelling, and stakeholder involvement, taking into account the various business models behind new mobility propositions. All our development is validated through an iterative approach. Advanced methods and tools are required to analyze, assess, and monitor these new mobility solutions and policies including new data management techniques. The toolkit (in the form of a dashboard) incorporates these methods and tools providing researchers, planners, and policymakers a visualization of the results through a GUI (Graphical User Interface). Fig. 1 gives a schematic view of the toolkit.

2.2. Toolkit design

For each of the use cases algorithms are designed taking the current state of the art into account and adding new elements to it. These algorithms are currently being developed, with three of the six use cases ready by May 2022. The algorithms are coded in Python and first tested under lab conditions. Then the code is ported to a back-end engine (forming part of the toolkit) that will run an instance of Amazon Web Services (AWS) with the support of a spatial database engine (PostGIS) and a big data storage (S3-buckets) and input/output file handling capabilities. To perform smooth operations, the entire endeavour will operate using private and public APIs, with the front-end system containing access control regulations (Cognito) and the visual part of

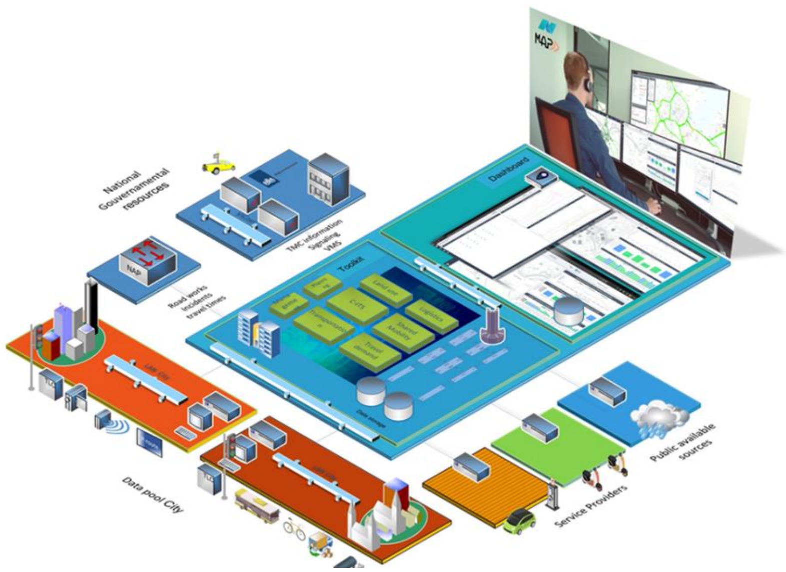

Fig. 1. Schematic view of the architecture of the nuMIDAS toolkit

the different use cases, e.g. graphs for geographical interpretations, monitoring of key performance indicators, etc. Within a use case, different scenarios can be created and calculated and presented in the dashboard (see Figure 2).

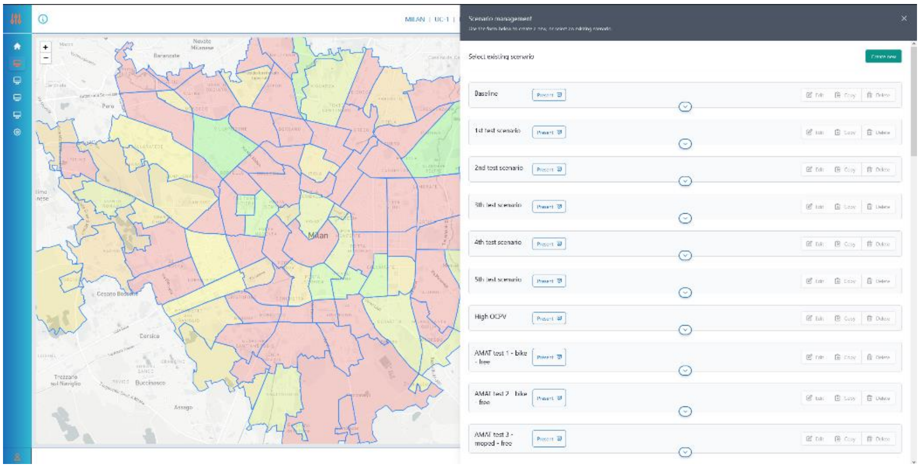

Fig. 2. nuMIDAS scenario management menu

Within the nuMIDAS toolkit design, special attention has been given to the set-up of the structure of the use cases and scenarios as well as the interaction of the back-end and front-end. The first development step is done by setting up mock-ups of the dashboard's front-end (web page design) and creating a storyboard based on the end-user experience with the following steps:

- Choose a use case (project) within a user group of a city, change parameters, upload or download data in the form of a CSV and run a calculation;
- View the results geographically and in graphs, compare different calculations, and be able to save the results in a scenario slot.

The implementation started with the set-up of the user management of the toolkit access which is organised in Cognito. Cognito enables the 'add user' 'sign-up', 'sign-in', and access control to the web and mobile apps quickly and easily. Cognito is HIPAA eligible and PCI DSS, SOC, ISO/IEC 27001, ISO/IEC 27017, ISO/IEC 27018, and ISO 9001 compliant. Within the Cognito environment, the user access to the toolkit and the access on the city level is arranged.

The nuMIDAS toolkit is built up based on use cases organised per city. Within a city's domain, multiple model runs by end-users are possible for which the level of scenarios is created. Subsequently, cities could have access to more than one use case, which is the case for Milan and Leuven. While developing the first use case and the toolkit in parallel, based on the first experiences, a design team created several drafts of a more flexible and transferable environment for the second iteration. The main goal is the use of clear naming conventions and configuration to enable the developers to

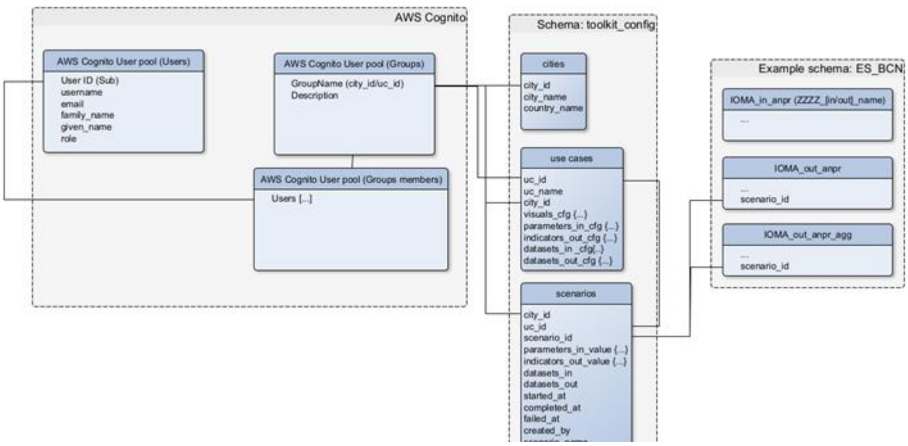

Fig. 3. nuMIDAS flexible configuration setup for users, cities, use cases and scenarios

understand and recognise all the components of a use case and cities and scenarios within the toolkit environment. Fig. 3 shows the generic setup of the user pool in Cognito, general toolkit configuration using JSON (JavaScript Object Notation) descriptive strings and the naming of the input and output of the use cases.

With the first version of a use case implemented, end-user testing sessions are organised with policymakers from the cities to test the technical and functional setup and get feedback in the form of requirements and bugs for the interface and use case configuration. All requirements and bugs are tracked with the Mantis bug tracking system and analysed and evaluated weekly.

3. Case Study: Milan

3.1. New mobility challenge

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 economically 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 in a poor level of service and a negative impact on the level of 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 the operator's earnings and hampering the financial viability of provided services. Therefore, the use case described in this paper revolves around the development of a high-level DSS (decision support system) 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. Indeed, as already seen in Studer et al. (2020) and Böhm M., Studer L., Mans D. (2010), the use of decision support systems and toolkits for decision support has become, over the years, of fundamental importance in the transport sector. The nuMIDAS tool should ideally account for demand fluctuation caused by unexpected events, such as the COVID-19 pandemic, which caused either an increase or decrease in the level of demand for certain transport modes (Fisher et al., 1994). This tool will enable preliminary planning of shared mobility services to be deployed within the specified area to support the issuing tenders including a data-driven perspective.

3.2. The nuMIDAS solution

The main output of this Milan use case is considered an important intermediate step toward the definition and enforcement of proper fleet management policies considering the long-established practice of service operators to rebalance their fleet to successfully meet existing demand (Shaheen and Cohen, 2016; Nikitas, 2019). In this respect, if the fleet size is a priori inadequate the effectiveness of such policies will most probably prove ineffective, hampering both the financial viability and level of service. As it appears, there are two perspectives from which the optimal value for the fleet size should be identified, reflecting both the level of service and the financial viability of provided services. In the context of this use case, these perspectives are understood and termed as the “perspective of end-users” and the “perspective of service operators”. Moreover, provided that policymakers should in principle achieve a balance between these perspectives, the tool enables its users to find an optimal compromise.

The above analysis indicates that the first tool of the nuMIDAS toolkit provides a solution to an optimization problem. This problem involves the identification of a value for the fleet size of a mobility service that jointly maximizes demand coverage and the profitability of service operators considering both its stochastic and multi-periodic dimensions. The multi-periodic dimension concerns the number of vehicle trips provided as an input to the calculations, which is addressed on an hourly basis. The stochastic dimension concerns the specific time within an hour at which each traveller is considered to require a vehicle, which is approximated through probability distributions and/or empirical data. The tool report to its users, apart from the value of the optimal fleet size, several indicators related to demand coverage, expected profits of service operators, walking time, and waiting time.

3.3 *First results*

New sharing services, or extensions of the existing ones, can then be planned based on the outcomes of the nuMIDAS tool. The dashboard allows tuning parameters of the algorithms to compare different scenarios, depending on the weight given to conflicting objectives, namely the user perspective based on reducing the waiting time and the distance from the first available vehicle, and the operators' perspective which is contingent on making a profit.

The policymaker/transport planner will use the dashboard to link data sources and input parameters and to visualise the results of the computation in a user-friendly environment.

Regarding the City of Milan, it has a population of 1.4 million and an area of 182km^2, with a density of 7000 inhabitants/km^2. Before the Covid period, Milan mobility systems satisfied the demand of over 4,2 million city users. Moreover, the Milan city area modal split is shown in Fig.4.

Regarding shared mobility in Milan, at the moment there are 20 shared mobility services provided by 18 operators divided as presented in Table 1.

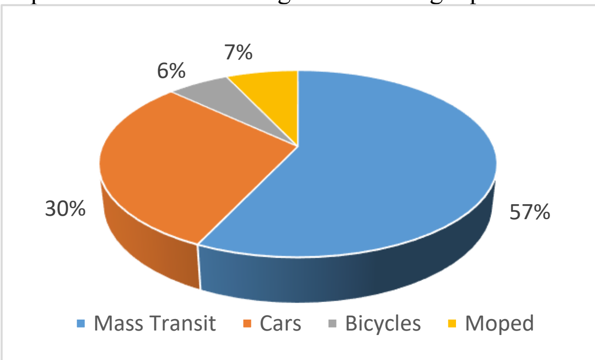

Fig.4. Modal split in Milan

Table 1: Shared services in Milan

Sharing Service	Free Floating (n°)	Station Based (n°)
Bike	3	1
Car	3	1
Kick-Scooter	7	0
Moped	5	0

Some input parameters are required to run the tool. Specifically, the following data inputs are requested:

- Selection of the type of mode to be analysed (bike, moped, kick-scooter, or car-sharing): it is the mode of transport utilised 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).
- 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. Average user walking speed(km/h): it is the average speed of a pedestrian. In this case, the default value is 3,6 km/h.
- 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 user's perspectives: the weights are the coefficients that measure the relative importance of single elements (in this case 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.

For the simulations, it was decided to use the data from the car sharing-free floating service, which is the most used shared service in the city of Milan. In order to evaluate how the tool responds to the variations of some parameters, 5 scenarios have been defined. Three of them are based on the historical data of the car-sharing services in 2019 (scenario n°1, pre-pandemic scenario), 2020 (scenario n°2) and 2021 (scenario n°3), whereas the remaining two are hypothetical scenarios. Specifically, in scenario n°4 the fares have been discounted by 20%, the minimum and maximum fleet are lower than in the previous scenarios, and the mean duration of the trip is the same as in scenario n°3. In scenario n°5, fares, minimum, maximum fleet size, and mean trip duration are the same for scenario n°4, but the expected daily demand is higher than in scenario n°4. All input parameter values are presented in Table 2. Moreover, the operating cost per vehicle per minute is an estimated value. Finally, at this stage, it was preferred to keep the weight values fixed (0,5 both for user and service operator) and focus attention on the variation of the other input parameters.

Table 2: Input parameter values for each discussed scenario

Input	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5
Expected daily demand (trips/day)	16400	7500	8100	10000	15000
Size of the area of interest (Km2)	14	14	14	14	14
Operating cost per vehicle per minute (Euros)	0,05	0,05	0,05	0,05	0,05
Expected revenues per minute of rent (Euros)	0,29	0,29	0,29	0,25	0,25
Average users walking speed (Km/h)	3,6	3,6	3,6	3,6	3,6
Mean Trip duration (minutes)	30	70	50	50	50
Weighting factors assigned to service operator	0,5	0,5	0,5	0,5	0,5
Weighting factors assigned to user	0,5	0,5	0,5	0,5	0,5
Minimum value of the fleet size	1860	1620	1260	500	500
Maximum value of the fleet size	3100	2700	2100	2000	2000

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 carried out 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 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.

Table 3: Model output for each discussed scenario

Output	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5
Demand Coverage (%)	100	100	100	98,9	98,4
Average walking time (min)	00:00:00	00:00:00	00:00:00	00:00:00	00:04:40
Average waiting time (min)	00:00:00	00:00:00	00:00:00	00:00:00	00:00:00
Optimal fleet size	1860	1620	1260	574	812
Optimal fleet size end users 'perspective	1860	1620	1260	647	961
Optimal fleet size operators 'perspective	1860	1620	1260	500	662
Profit service providers (€)	6.334	34.449	25.597	81.140	124.100

Output parameters of the model and their values for each scenario are presented in Table 3. From the results, it is possible to state that the tool models and reproduces the process that underlies the functioning of sharing services, even if some parameters still need to be better calibrated. However, looking at the results it can be seen that the profit-related output is overestimated. This depends on the fact that the operating cost is a value that is not known and is not published by any service operator and although the costs are unknown, such high profits seem completely unlikely. In conclusion, this tool, being a decision support tool, has as its objective not to find a single value, but to support the public decision-maker through the exploration and comparison of different scenarios.

3.4 Usability and end users experience

This tool will allow the Municipality of Milan to have the granularity of the information categorized by the four modes of shared mobility in Milan (Kick scooter, Bike sharing, Moped and Car sharing) and also differentiate them by the two major mobility types which are station-based and free-floating. The differentiation between all shared mobility modes is key in the case of Milan, as the authorized fleet, the per-minute fare, the daily rides and the geographical coverage widely differ per mode. In that sense, having the possibility to estimate the ideal fleet size of each mode separately provides the detailed information necessary to enhance the planning process of each one of the shared mobility services regarding the accuracy of the definition of the fleet size included within tenders.

In order to test the tool, both in terms of results and tool usability, a short interview was conducted with the manager of shared services for the city of Milan during a usability test performed on the last 22nd of April. Factual, which is one of the nuMIDAS partners, structured the test by using concrete questions regarding the software's interface and results. The conclusions of the usability test regarding the results rely upon the fact that the toolkit is intuitive and easy to use, and according to the policymaker (who has the role of whom could be considered a typical end-user), the results seem accurate and could correspond to a close estimation the required outputs.

Related to the results, the outcome data of this study case could give the Municipality of Milan and other municipalities that will use the tool comprehensive insight into the differences of each sharing mode regarding fleet size as it allows public administration users to include specific input that corresponds to a mode and then the results account for that specific mode so it could be used within each specific tender requirements for every four modes of shared mobility.

Also, within future public tenders addressed for all four shared mobility modes, this tool could be used to specify the number of the required fleet size that accounts for a balanced trade-off between the economic profitability of operators and the required fleet size to give sufficient geographic coverage of each service. Specifically, this tool will give more insight into the ideal fleet size for each mode without incurring economic losses for operators, while maximizing the possible fleet size in order to offer sufficient geographical coverage.

4. Conclusion and future works

The main milestones at the city level are that the developed use case will help Milan and other cities that will use the toolkit, and raise awareness about the importance of working with a data-driven approach within mobility planning and policymaking within the public administration and private sector. Similarly, this toolkit could contribute to achieving the consolidation of modelling tools used within the planning phases of policymaking to increase the capacity and accuracy of response to the current needs of the population regarding urban transportation. Within the Municipality of Milan, it is important to understand the importance of using a data-driven approach when defining a balanced trade-off between the economic profitability of shared mobility operators and the ideal fleet size that could permit a sufficient geographic demand coverage of the city. The shared mobility use case deployed by nuMIDAS can help the municipalities facilitate the use of new mobility data methodologies and tools. In the coming months, in addition to the finalisation of the other use cases, the second use case concerning the city of Milan will be also implemented. Particularly, this use case targets the allocation of existing shared mobility services' supply (i.e. operable fleet) to specific sub-areas of a metropolitan area to minimise economic losses of service providers and ensure an acceptable level of service for citizens, in line with the principles of equitable transport systems.

In conclusion, the toolkit is still "in progress" but at the time of the conference (November), it will be fully developed.

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