Towards an Urban Smart Mobility: Preliminary Results of an Experimental Investigation in Artena

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Abstract. With a higher awareness of sustainable development issues, the social costs of externalities of urban mobility have become unbearable. Whether in major cities improvement of transit may mitigate some of these drawbacks, in small municipalities countermeasures can be very challenging. Within this context, the "Smart Urban Mobility Management" (SUMMa) project it is trying to implement new technologies by making use of modern digital technologies and 5G communication networks for managing transportation systems in a small town. In this paper an application of a smart mobility paradigm based on a digital platform employing an enhanced Mobile Broadband, massive Machine Type Communications and Mobile Edge Computing, is presented. The digital platform has been conceived to help Artificial Intelligence algorithms for recognition image and interpretation of traffic field data, collected by H-D cameras. The system has been used to evaluate Origin-Destination flows on a real time basis. The estimated O/D matrix together with the collected traffic counts can be used in order to develop and calibrate a travel demand prediction model that will allow to evaluate urban mobility externalities. Preliminary results obtained on a test site located in the city of Artena seem to indicate that the proposed system is promising in capturing vehicular traffic pattern.

Keywords: Smart Mobility · Smart Road · SUMMa Project · 5G communication technology · AI technology · O/D matrix

1 Background

With the increasingly number of travels from rural areas to cities, especially with an increase of global population, several cities, all over the world, have the ambition to became more sustainable and smarter [1]. Recently, first with Agenda 30 and its 17 UN Sustainable Development Goals [2, 3] for 2030, and secondly with the Next Generation

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EU in Europe [4] that give a great impulse to address the problem of the urban mobility, the problem of create smart and sustainable cities is more critical than ever [5]. However, these two adjectives seem to be very related and somehow exchangeable because Smart Cities have the urgent need of new technological and digital transportation infrastructures [6] to offer accessible and intermodal mobility solutions and services [7]. According to Lai et al. [8], the problem to identify uniquely a definition of Smart Mobility is due to the several identities involved in this process and the different technologies that a city may offers [9]. According to the European Commission [10], "A smart city is a place where traditional networks and services are made more efficient with the use of digital solutions for the benefit of its inhabitants and business".

But how to evaluate how smart and sustainable is a city? According to Garau et al. [11], six variables need to be tackled in account (public transport, cycle lane, bike sharing, car sharing, private mobility support system, public transport support system) to generate a smart mobility synthetic indicator, that allows to compare cities among them to assess how smart and sustainable they are [12].

To transform a city in a Smart City, IoT technologies need to be adopted [13, 14] and this is possible today with the digitalization [15], with implementation of the maximum performance of digital infrastructure (such as 5G) and the recent development and spread of Artificial Intelligence and machine learning technologies [13] for transport automation and intelligent transport system (ITS) [16–18]. Although the improved technologies play a fundamental role in collect and analyzed a huge amount of data, this launch to digitalization and modernization of infrastructures and mode of transport, need to be assisted by strong Sustainable Urban Mobility Plan (SUMP) that have to offer a clear vision in the long period time [19].

Given this new impulse to re-think the European cities in a smarter way (in Italy great effort are made with the MIT Decree 70/2018 of the Italian Ministry of Infrastructures and Transports [20]), the city of Artena has become the protagonist in the hosting of the Smart Urban Mobility Management or S.U.M.Ma National project, within the Smarter Italy Project [21]. With the aim to enhance new digital technologies such as IoT (Internet of Things), AI, Blockchain and the use of 5G communication networks, to improve the competitiveness of the transportation systems through new services for the management and modernization of both urban and rural mobility systems, in this paper the preliminary results are shown.

1.1 Smart Urban Mobility Management (SUMMa) Project

The goal of the project "Smart Urban Mobility Management" (Summa) is to make the most of the performance of a 5G network in terms of bandwidth and available power compared to Smart Mobility scenarios. Specific studies and tests will be carried out to optimize mobile communication and obtain trade-off curves. The project proposal involves the creation of a system for the analysis of mobility thanks to the use of sensors and advanced cameras that exploit specific algorithms based on Neural Networks to recognize subjects and objects framed.

A simplified representation of the Summa platform architecture is shown in Fig. 1.

This project is aimed at the enhancement of the Digital Technologies promoted by the Government Call as an enabling factor and necessary to increase the complexity and

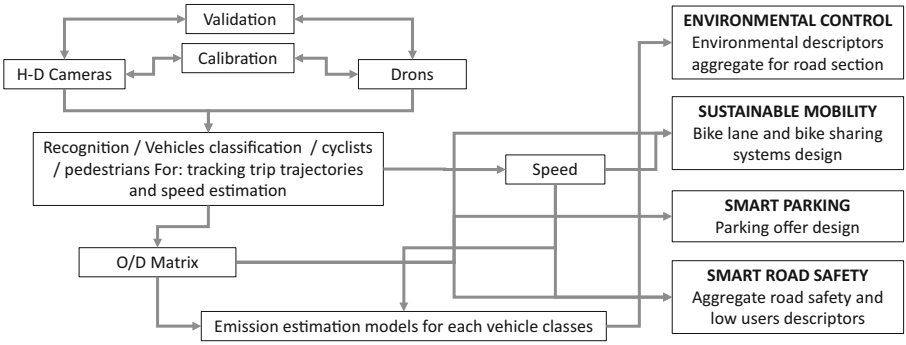


Fig. 1. Simplified SUMMa platform architecture.

competitiveness of the Italian Logistics system, considering the importance of human and commodity flows that affect the entire national supply chain, from tourism to exports of Made in Italy.

Digital technologies such as iot (Internet of Things), AI (Artificial Intelligence), Blockchain and the use of new 5G communication networks, as well as making logistics processes more efficient, may contribute to the structuring of new services for the management and modernization of transport systems.

The project idea involves the creation of a modular architecture in which to experiment with the simultaneous implementation of enhanced connections Mobile Broadband (eMBB), massive Machine Type Communications (mmtc) and Ultra-Reliable Low-Latency Communications (URLLC) in a 5G network to support Sustainable Mobility, and the implementation of services that exploit the potential of Mobile Edge Computing. Mobile Edge Computing allows to implement low latency and location-based services; it is an essential technology for the realization of the services proposed by the project, which will offer the computing platform for the implementation of AI algorithms combined with image recognition and interpretation of data from the field. Therefore, it will be possible to estimate the flows close to the camera detection sections and to process an O/D matrix for a given standard day and a certain time slot.

This allows us to estimate possible congestion effects and, being within the reach of citizens, allow them to choose any alternative routes avoiding long queues and possible delays.

Moreover, the platform allows to estimate, averaged data in the 24 h of a typical day, of environmental pollution that allow to realize of the best ones to mitigate such problem.

However, to concretize the data provided by the platform, in terms of traffic counts and O/D matrices, there is a need to know the municipal territory of Artena and then to determine a model for travel demand and for the corresponding transport supply model.

2 Travel Demand Forecasting Model, TDFM

The transport demand model (TDFM) [22] can be summarized as follows:

$$d_{od}[K] = d(SE, T) \tag{1}$$

Where

- d_{od} is the average traffic flows between the origin zone "o" and destination zone "d";
- K are all features such as activities and mode of transportation of the specific study area
- SE is a vector that represent features (K) of socioeconomics variables;
- T is a vector that represent service level attributes of the transport delivery system.

Therefore, it aims to associate to the mean value of the travel flows the characteristics K, which can be summarized in:

- The purpose of the trip;
- Time interval in which the trip takes place;
- The area of origin and destination of the trip;
- The mode of transport used during the trip;
- The routes chosen.

The TDFM consists of four sub models by virtue of the characteristics listed above. It results to be a cascade model where the data of input of the successive sub model are the data of output of the previous sub model. Such sub-models are divided as in Fig. 2.

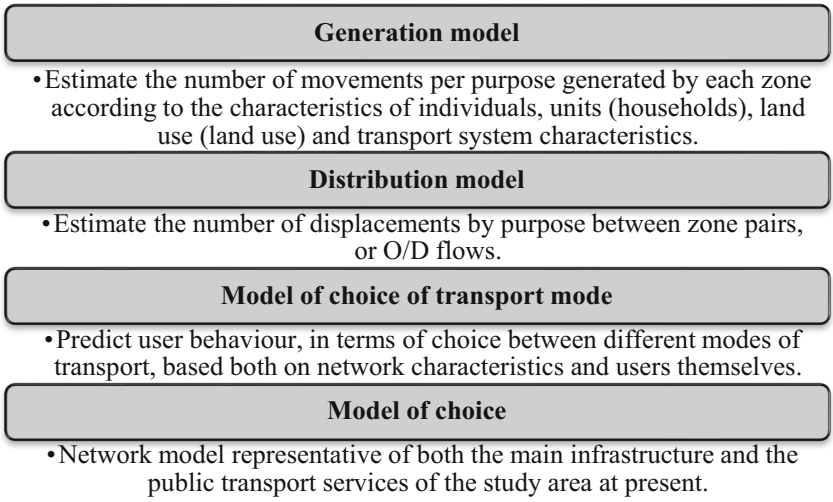


Fig. 2. Simplified TDFM architecture.

This model can therefore be represented in the following way:

$$d^{i}_{od}(s, h, m, k) = d^{i}_{o}(sh)p^{i}(d/osh)p^{i}(m/dosh)p^{i}(k/mdosh) \tag{2}$$

Where:

- s is a specific purpose for the trip;
- h is the time taken to make the trip;
- m is the mode used to carry out the trip;
- k is the path chosen by the user to make the trip;
- $d^i_o(sh)$ is the generation model;
- $p^i(d/osh)$ is the distribution model;
- $p^i(m/dosh)$ is the modal of choice of transport mode;
- $p^i(k/mdosh)$ is the model of choice.

3 Case Study - Traffic Modeling

3.1 Zoning and Road Network Structure

For this case study, having carried out preliminary studies [26] on the distribution of the population and the relative productive activities, an aggregation of the internal traffic zones is proposed equal to 11, compared to the microzoning proposed by ISTAT [23], represented in Fig. 3.

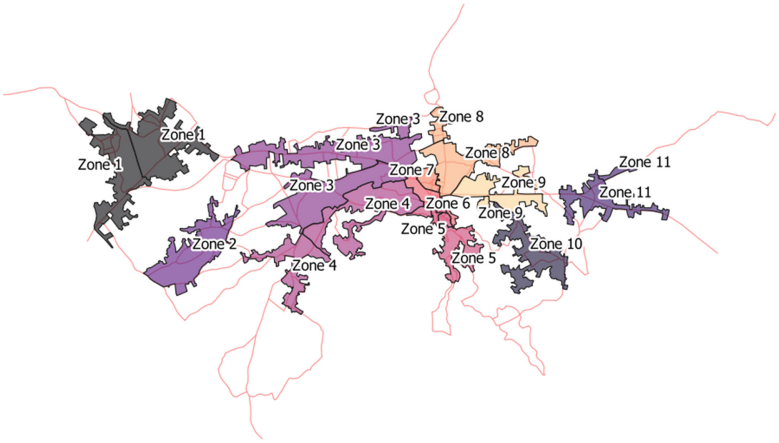


Fig. 3. Zoning of Artena [24]

To define the basic road network, in Fig. 4, the types of roads considered are:

- State roads;
- Municipal roads;
- Local roads.

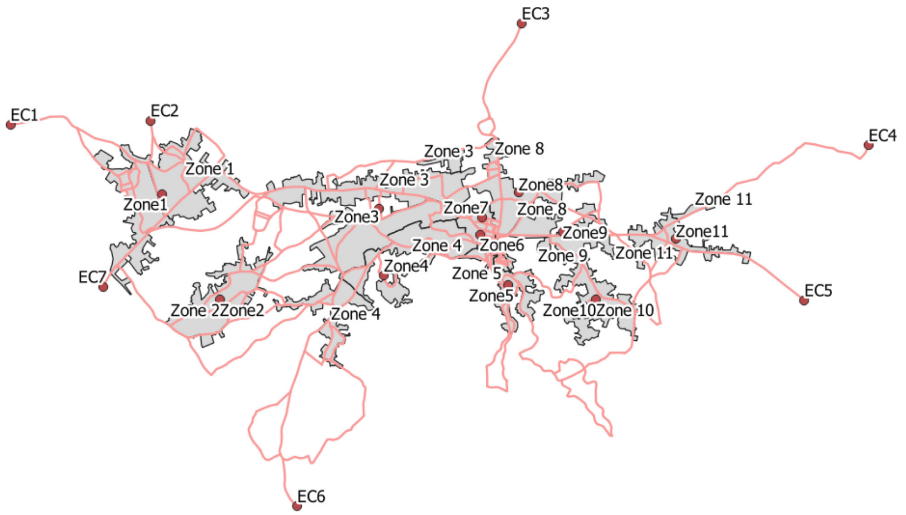


Fig. 4. Graph of Artena's Road network [24]

4 Monitoring of Vehicle Flows Through Fixed Cameras

The study foresees the monitoring of vehicular flows with automatic detection techniques through video images based on the use of cameras, which allow to continuously detect the traffic scenes that take place on a road section. The cameras offer a spatio-temporal representation of the vehicular flows, so it is necessary to process the video sequences through methodologies that allow an interpretation of the content of each image (spatial analysis) and their correlation in time sequences (time analysis).

To design an automatic detection system with video images it is necessary to use specialized hardware and software, especially whether video sequences in real time are automatically analyzed, important aspects concern the transmission and reception of data, number of cameras per control system, zone detection for monitoring and finally "image detection" processing and analysis in real time.

4.1 Camera Detection and Positioning Method

The proposed method of traffic detection is based on the use of a video monitoring system through the presence of cameras, which allow the continuous detection of traffic scenarios that take place on a section or at a road intersection. Cameras with artificial intelligence algorithms on board - installed in strategic points of the city - can recognize, classify, and count vehicles, track their movements, and detect their speed.

In more detail, the latest generation of cameras can extract precise data on vehicles (type, color, mark, number plate, direction, speed) from the images and, based on the algorithms adopted, detect anomalies in their behavior (vehicle stopped or wrong-handed) and locate their movements within the city. In addition, they automatically detect traffic jams, accidents, abnormal events and provide statistics in temporal (and real-time) succession of traffic conditions.

Intelligent image processing allows to send event notifications and alert operators in real time. In addition, all the data collected by the cameras gives a timely picture of city mobility, with the consequent planning of an efficient management of vehicular. The European Commission is currently working on a proposal for a Council Directive on the approximation of the laws of the Member States relating to the protection of the environment.

After analyzing the internal road network of the municipality of Artena and its external connections, 7 strategic points were identified: 4 refer to the perimeter area of the urban center and then detect traffic in or out of Artena to neighboring municipalities external sections, and 3 are arranged internally to the municipality. The identification of these strategic points allows to optimally place the cameras to be allocated.

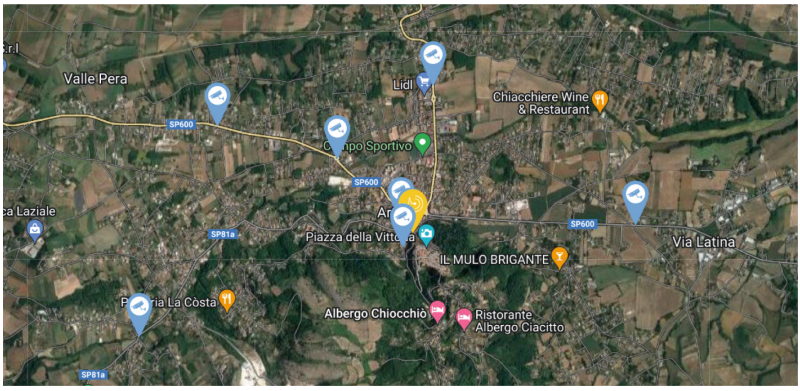


Fig. 5. Location of the cameras [25].

In Fig. 5 are shown in blue traffic detection cameras, in Fig. 6 there is in yellow the camera that serves as an environmental station.

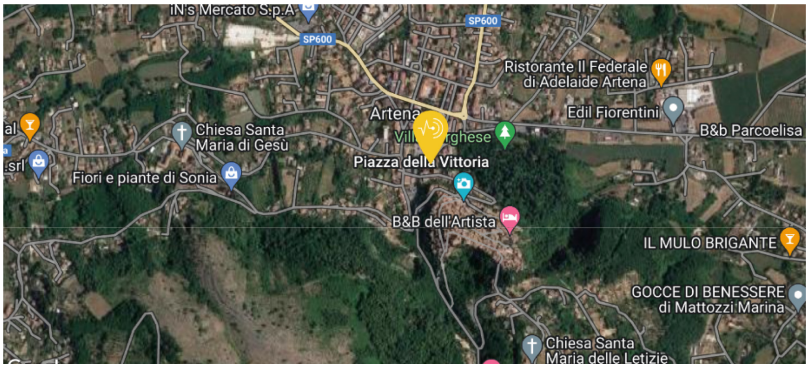


Fig. 6. Location of the environmental station. [25]

4.2 Algorithm for the Study of the Movements Intercepted by the Cameras

Once the position of the cameras had been defined, it was necessary to identify the relevant traffic data intercepted by them, which are divided into:

Trips within the municipality of Artena;
Trips from the municipality of Artena outwards;
Trips from the outside towards the town of Artena;
Through-traffic trips (from outside the Artena area to outside the Artena area).

A post-processing algorithm has been developed and implemented to gain relevant traffic information by the network of automatic detection cameras. In Fig. 7 and Fig. 8, the structure of the algorithm, by means of a schematic representation, is proposed in the two cases of streams intercepted by a camera on the cordon section and by a camera located in the inner urban area.

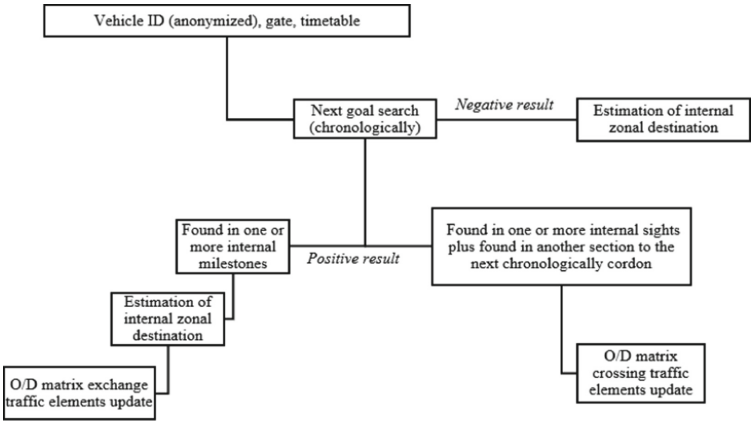


Fig. 7. Structure of the algorithm for the study of the streams intercepted by a camera on the cordon section.

All these relevant traffic information has been reported within a single Origin/Destination matrix in which trips within a single traffic zone (the so-called intra-zonal trips) have been neglected.

The structure of this matrix provides information on the probability that a vehicle, intercepted by the internal cameras and by those placed in the external sections, can reach a certain traffic area or another. All this is expressed in probabilistic terms as the number of cameras is insufficient to cover the entire Municipality of Artena: if this had been possible, the destination of a vehicle would have been identified in deterministic terms.

4.3 SUMMA Platform for Algorithm Implementation

The platform SUMMA has been implemented in a specific Dashboard that allows to obtain the necessary data to carry out studies on the mobility of the municipality of Artena.

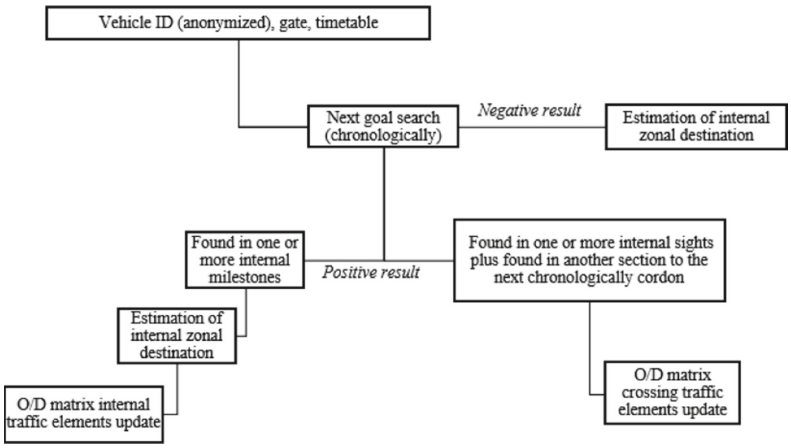


Fig. 8. Structure of the algorithm for the study of the streams intercepted by a camera on the internal section.

The home screen is defined as follows in Fig. 9.

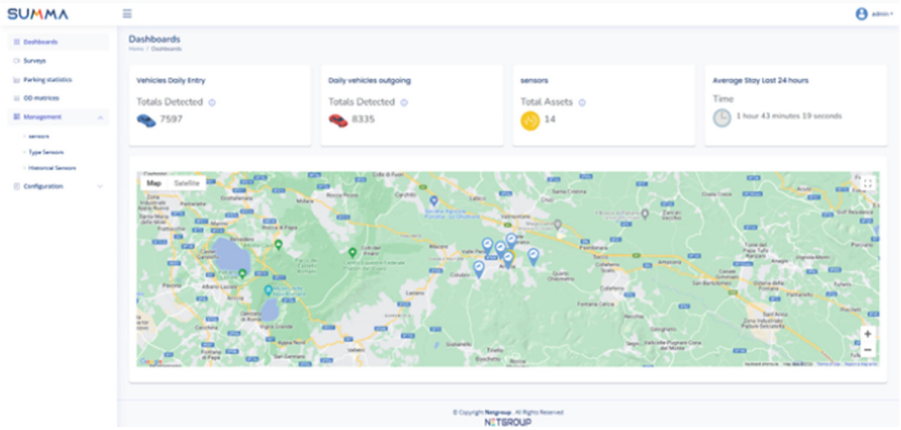
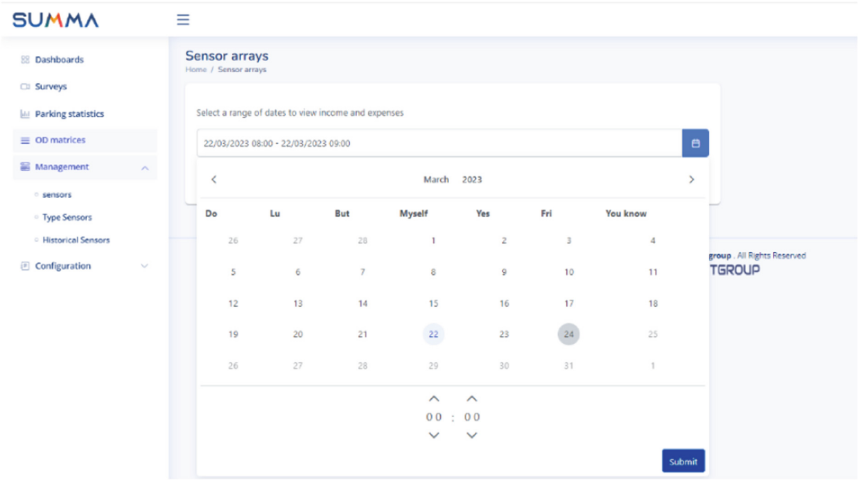


Fig. 9. Dashboard of SUMMA platform [26]

This platform allows, for a typical day and a user-defined time slot (Fig. 10a), to obtain the estimated traffic counts from the cameras and to derive the relevant O/D matrix, (Fig. 10b).

a)



b)

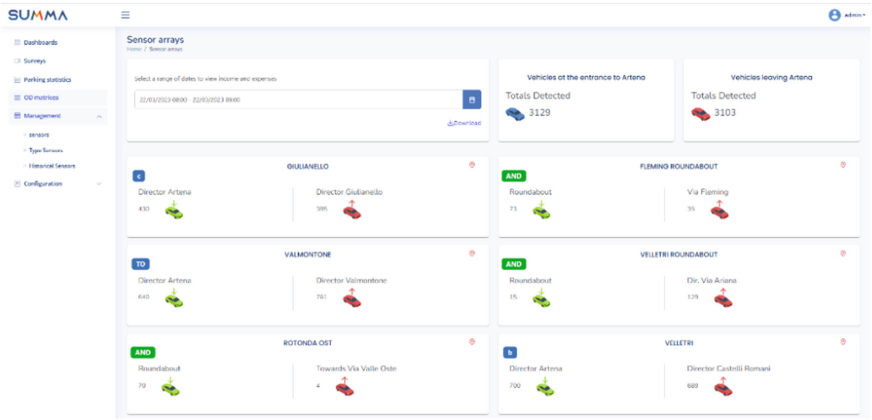


Fig. 10. a) Selection of day and time slot to extract data from, b) extracted data [25].

This traffic data will then be implemented on the development of a Travel Demand Forecasting Model by means of a macro-modelling approach. In detail O/D estimates have been used as information basis for a macroscopic analysis, to perform a traffic assignment, and to calibrate a traffic forecasting model at urban level.

The platform also allows, thanks to the presence of the environmental station, to obtain measurements on the environmental impacts averaged in the 24h period of a typical day as follows in Fig. 11.

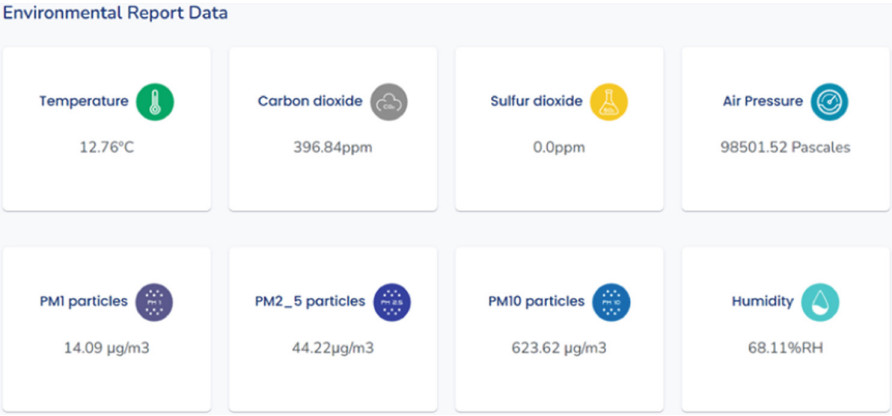


Fig. 11. Environmental Report Data [25]

5 Results Obtained: Route Choice and Traffic Assignment

To define the intervention measures aimed to improve the sustainability of the municipality of Artena in terms of mobility, the traffic model previously described, has been developed. With the data elaborated by the aforementioned SUMMA platform, several O/D matrix have been obtained. In addition, with the traffic counts available, the model was calibrated, and several analyses was carried out on specific time windows (peak hours) on a typical working day.

Below are the results of a typical day in the morning time slot (07.15 - 08.15) in terms of vehicular flow and saturation rate in Fig. 12a) and b).

As it can be easily detected by the analysis of the obtained results from Figs. 12a and 12b, road sections connecting city of Artena with the nearest municipalities are those affected by more high traffic flows compared with those pertaining the internal roads of the municipality themselves.

5.1 Calibration

Following the assignment of traffic by means of the User Equilibrium method the model needs to be calibrated with traffic counts provided by the cameras.

A comparison has been made between the calibration based on the O/D matrix derived by commuting traffic provided by National Statistical Office (ISTAT) within the Census data collection activities that is referring to the morning peak time 7.15–8.15 (see Fig. 13a) and the calibration based on the estimated O/D matrix obtained from the automatic detection cameras within the SUMMA platform (see Fig. 13b).

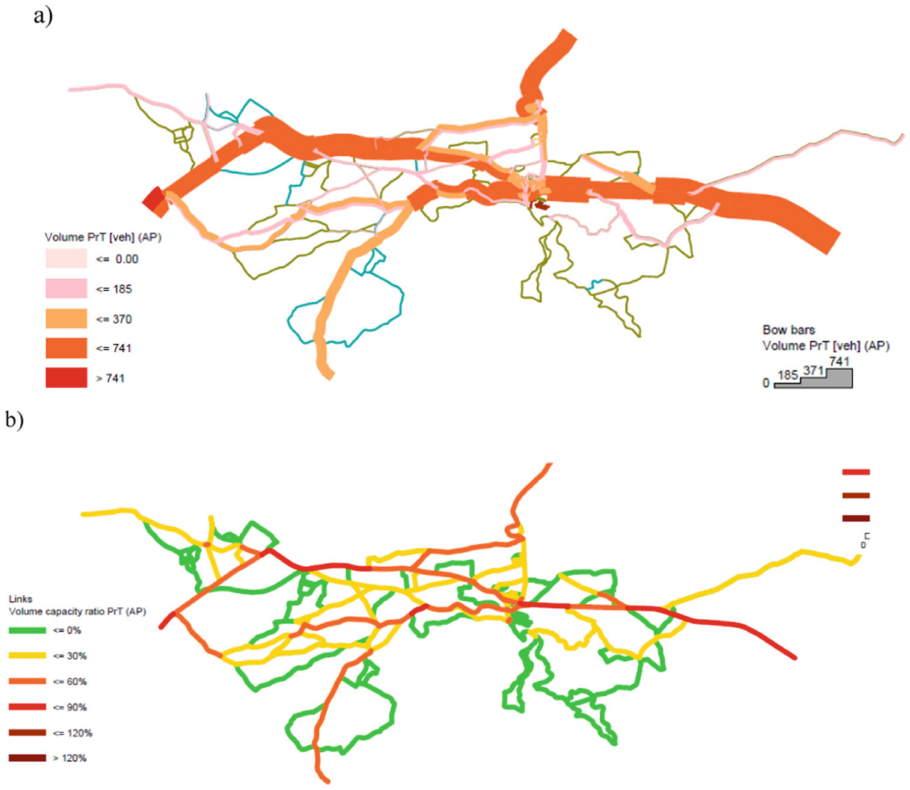
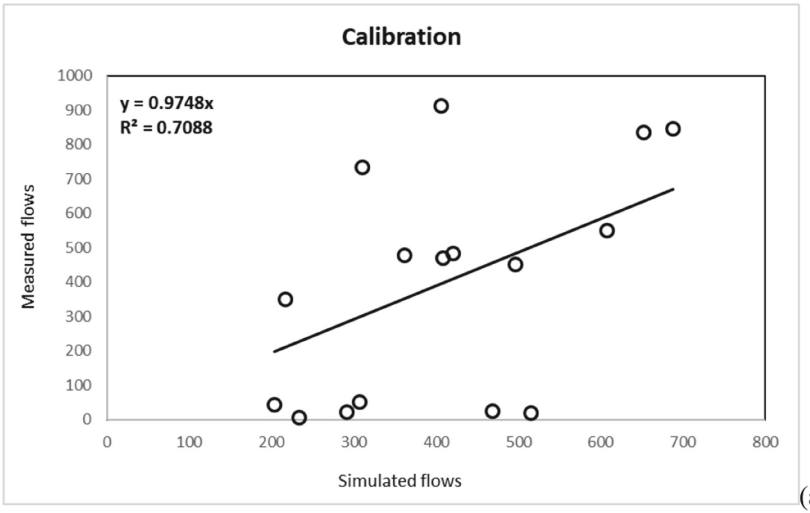
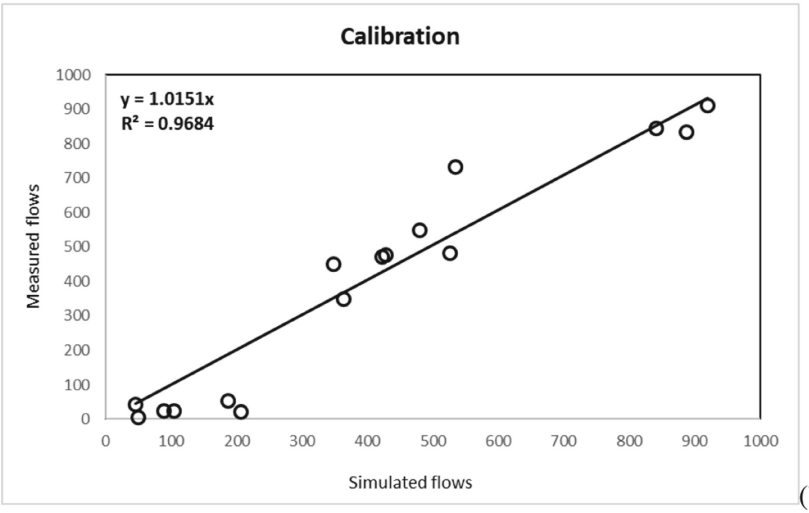


Fig. 12. Car and motorcycle mode traffic flow distribution for a) morning peak hour matrix and b) Volume capacity ratio.

As it can be clearly highlighted by these preliminary results, the calibration of traffic prediction macroscopic model performed on the estimated O/D matrix obtained from the SUMMA platform shows a better agreement between predicted and measured traffic flows than that obtained on the ISTAT matrix, exhibiting a higher Coefficient of Determination (R^2). It therefore seems that the proposed post-processing algorithm seems to better capture the mobility pattern in the examined urban area.



(a)



(b)

Fig. 13. Model calibration based on ISTAT O/D matrix a) and on estimated O/D matrix provided by the SUMMA platform b).

6 Conclusion

This article presents some results related to the development of the SUMMA project, promoted within the Smarter Italy project funded by Italian Ministry of Economic Development. The pilot project took place in the municipality of Artena and involved the design and development of a digital platform system for mobility analysis using advanced sensors, cameras that leverage specific AI algorithms and 5G communication infrastructure.

The data obtained by the platform has been implemented in a macroscopic traffic prediction model obtaining results in terms of network saturation and traffic volume throughout the whole relevant road network, although is not covered by the automatic detection cameras.

What it is found by comparing the calibration obtained from the O/D matrix provided by ISTAT and the O/D matrix estimated by the proposed post-processing methodology within the SUMMA platform, is that the far better results are obtained by means of this latter approach. Therefore, the proposed methodology for post-processing the traffic data collected by the network of automatic detection cameras seems to be able to better capture the real mobility scenario occurring in the municipality of Artena therefore providing a significant insight of traffic issues that will be effectively tackled by road managers, city planners and all relevant stakeholders.

What is certainly the subject of future research is above all the development of data acquired by the environmental camera to assess the impact that vehicular traffic generates on Artena and propose, based on the results obtained, the most sustainable choices according to Agenda 30 [2, 3].

Also, will be analyzed other traffic data, concerning different time windows.

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