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and the New Habitat
The problems and science of human settlements

SPECIAL ISSUE

Cities and Transport in the Mediterranean Region (Part 2 of 2)

Guest Editor: Prof. Dr. George A. Giannopoulos

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Ekistics and the new habitat: the problems and science of human settlements

The International Journal of *Ekistics and the New Habitat* is an online double-blind, internationally peer reviewed research journal. The journal publishes scholarly insights and reflective practice of studies and critical writing concerning the problems and science of human settlements. The field of Ekistics is mapped against a classification of settlement scale, from the remote village and rural township to global systems of dense smart cities, and increasingly the challenges of on-and-off world sustainable habitats.

In broad terms, papers in *Ekistics and the New Habitat* contribute to the scholarly discourse about the systemic nature of how humans design, build, link-up and transform their world. Articles examine empirical and non-empirical research and ideas that critique the necessary relationship between people, our human settlement designs and technological systems, and our natural and designed habitat. Models, case studies, rigorous conceptual work, design critique, smart-citizen education for smart cities, resource flows, network behaviour, and reflective practice are published in order to continually improve and advance the application of integrated knowledge that defines the epistemic telos of Ekistics.

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Ekistics and the New Habitat: the problems and science of human settlements is the 2020+ online and revised continuation of the ground-breaking and influential ideas published throughout the preceding print version of the journal in *Ekistics: the problems and science of human settlements* 1957-2006.

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Standard Call for Papers.

There are few scholarly journals whose papers archive the evolution of development and thought tracing back to 1957: *EKISTICS* is a rare exception. This background makes for an extraordinary historical collection of research and practices documenting how humans have colonised the planet and transformed our built habitats. The journal seeks papers from students, post-graduate candidates, academics and practitioners. We seek papers, typically of a cross-disciplinary nature that:

- Target any aspect of the *United Nations New Urban Agenda, in Habitat III*, including reference to the *Sustainable Development Goals* .
- Critiques *local, regional and global policy* of human settlement development, design and planning, and urban transformation
- Offers a critical description of the *core elements that define the liveability of human settlements* such as:

NATURE: Habitat foundations. How settlements rely upon, interact with, alter, or produce living ecologies, biodiversity, and climate.

PEOPLE: Physiological/biological and social-psychological needs and constraints. How settlements rely upon, interact with, or affect people's livelihood, safety, embodied and shared knowledge and skills, security and well-being – whether they are transiting visitors, settlers (citizens), or neighbours of settlements.

SOCIETY: Social, economic, educational systems, fiscal and political organisation. How settlements rely upon, interact with, or are affected by governance and leadership, vicarious or present communities, groups, markets, cultures, beliefs and values.

SHELLS: The envelopes that contain settlement functions. How the design, technologies and places created, altered or removed in settlements affect the functions and amenity of the settlement from the scale of personal shelter to the home, to urban business districts and precincts, to towns, cities or regions.

NETWORKS: Node-to-node systems and flows of resources, waste, data, people and information and communication systems. How the design, technologies and transport of goods, waste, energy, resources, water, food, people and information affect a settlement's functionality, amenity and viability.

SYNTHESIS: Combined, coherent design and knowledge. Physical design and planning; Ekistics theory expressed through evolving models and principles of habitat. How systems of systems may differ from small and remote, to large and urban-dense settlements and linked-up settlements in regions.

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   a. an introduction to a problem or topic outlining the need for or goals of the research,
   b. the key prior papers in Ekistics archives and other sources that best relate to the topic,
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We welcome book reviews. Submissions are copy-edited, normally 300-500 words, designed to share with the readership community interesting or provocative volumes, monographs, or edited books that may be of interest to scholars, practitioners and students of human settlements, Habitat III New Urban Agenda, and the Sustainable Development Goals of the United Nations.

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EDITOR'S DESK

IS DATA THE SOLUTION?

2021, Vol. 81, Issue 1

Welcome to the first special issue of the international journal *Ekistics and the New Habitat: The problems and science of human settlements* for 2021. Although this issue is appearing at the outset of 2022, delayed as it were by the impacts of the global pandemic, it contains articles that address ongoing concerns within the Mediterranean region. Firstly, I would like to thank our guest editor Prof. Dr George A. Giannopoulos and the contributors for their energy and patience, without which this issue would not have come to fruition. It is with delight, therefore, that we can now present this outstanding range of contributions to the readers.

The special issue begins with Prof. Giannopoulos' editorial which sheds light on the difficulty selecting contributions that will be of interest to the general reader, and that will adequately reflect the diversity and specific concerns of the region. This insight reminds us of the challenges and benefits of conducting research at the regional scale, whilst maintaining an interest in smaller scale case studies and analyses. The issue then takes us to Cairo where we discover research exploring the use of Artificial Intelligence (AI) in traffic management systems. Shafik et al. present the fine-grained control and flexibility made possible by new forms of AI, providing great insight into the applications and effects of such technology. The reader's attention is subsequently drawn to the Western Balkans where a debate over the benefits of implementing a network-based or corridor-based model for regional transport solutions is examined. In this article, Dionelis & Giaoutzi introduce the stakes of regional transport development and highlight the complexities of planning decisions for regional players who operate within global networks. The reader is then invited to focus on the urban scale where a case study concerning bus lane usage in the eastern part of Thessaloniki, the second largest city in Greece, provides an opportunity to analyse public transport in the context of an urban area consisting of approximately one million inhabitants. From Greece the reader moves on to Spain where Angel Aparicioo makes another appearance between the covers of *Ekistics and the New Habitat* to explore the social dimension of sustainable urban mobility. This theme is further explored by Tsami & Bekiaris who focus on the use of crowdsourcing apps as a means of enhancing urban mobility. Extending this type of analysis, Palatzas & Nalmpantis address the issue of e-scooters; turning to the data from multiple cities to explore this not-uncontroversial mode of transport. Finally, Mylonas et al conclude the reader's journey with a discussion of intelligent transport systems in Greece now and into the future. Their focus draws together the prominent themes in this special issue that seem to highlight the ever-increasing role that data, AI, and 'smart technologies' are playing in the development of solutions to transport and network challenges.

Dr Ian Fookes
Deputy Editor | *Ekistics and the New Habitat.*

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The problems and science of human settlements

2021, Vol. 81, Issue 1

Special Issue: Cities and Transport in the Mediterranean Region (Part 2 of 2)

Guest Editor: Prof. Dr. George A. Giannopoulos

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Contents

Editorial

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This issue is the second part of a two-part ensemble of special issues of the *Ekistics and the New Habitat* journal on the general subject of 'Cities and Transport in the Mediterranean Region'. As in part one, belatedly published in late 2021 due to the global pandemic, it presents a collection of analyses and future engagement papers on key topics and transport-related issues faced by countries in the Mediterranean region. The majority of the papers address primarily transport planning and organizational aspects, and refer to the wider Balkan Peninsula, Egypt, Spain, and Greece.

Planning and sound organizational structures are fundamental tools for achieving urban transportation systems that are climate-friendly and environmentally sustainable. Unfortunately, such systems are yet to be achieved in most Mediterranean countries. New and more environmentally friendly transport technologies are also needed especially as the ongoing fourth industrial revolution is fostering new clusters of urban economic activities. The most imminent of such technologies is integrated electric and connected mobility applied within broader intelligent transportation systems. Increasingly, these systems are part of the day-to-day transport operation in so-called 'smart cities' within urban areas of many European Union countries, so there exists a valuable body of experience nearby.

When selecting the papers for this (and the previous) part of the special issue on 'Cities and Transport in the Mediterranean Region' we were faced with several problems. Firstly, we had to cover many countries with diverse systems of governance and cities at various stages in the implementation of their urban transport systems and planning practices. Secondly, as the Mediterranean region consists of more than twenty countries, any systematic or uniform discussion of the problems and challenges facing such a diverse region remains a challenge. Blanket, one-size-fits-all, solutions are often inappropriate in local contexts, just as identifying best practice from contextualized case studies remains a complex exercise in translation and adaptation. In response to such complexity, *Ekistics and the New Habitat* provides a site where case studies and research from a range of scales and scopes can be gathered and discussed. These reports can be classified and situated using the ekistics grid developed by C.A Doxiadis. The grid ranging from the individual person (Anthropos) to the global population (ecumenopolis) and encompasses developments of human settlements overtime. The result is a searchable collection of diverse yet comparable studies dating back to the *Ekistics* journal's first issues in the 1950s. Keeping this boarder research context in mind, and with the goal of disseminating good practices and success stories clearly in our sights, we opted to use the limited space of the present special issue to introduce characteristic examples of sustainability in urban mobility that we hope will be of interest to a diverse readership.

The papers in this Part II of the special issue provide a glimpse of the various ways in which Mediterranean region countries are facing the challenge of improving the environmental quality and livability of urban habitats; they also demonstrate that our region is and should continue to be at the forefront of the struggle to build a sustainable future.

Development of Online Vissim Traffic Microscopic Calibration Framework Using Artificial Intelligence for Cairo CBD Area

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Abstract

This paper makes a notable contribution to Transportation Planning in urban areas by considering the application of a key transportation Planning software package for the traffic conditions in the Central Business District of Cairo. For urban areas with heterogeneous and very congested traffic conditions and uneven driving behavior such development can be very useful. The paper shows how a microscopic simulation model using a Multilayer Feedforward neural network (MFNN) to calibrate online the VISSIM package driving parameters' values based on predictions of travel time and traffic flow on the network elements. The two-step calibration procedure is faster and more applicable for on-line models than the approaches followed in current literature that require time-consuming iterations for model calibration. Also, this research uses combined Artificial Intelligence models (Long-Short Term Memory based Recurrent Neural Networks - LSTM-RNNs) and Multilayer Feedforward neural network (MFNNs) and calibrates them based on the driving behavior and traffic condition on successive time intervals. In this way, the prediction of the future traffic condition is based on actual traffic conditions on the past intervals and the actual driving behavior.

1. Introduction

The role of traffic simulation models' application has rapidly increased in recent years. Macroscopic, mesoscopic, and microscopic traffic simulation models have been calibrated and validated with the aim of judiciously replicating the actual observed field conditions for online applications (Bartin et al., 2018; Figueiredo et al., 2014; Khaled., 2005).

There are three types of traffic simulation models classified by the level of detail: macroscopic, microscopic, and mesoscopic. Macroscopic models aggregate the characteristics of the vehicles and consider the whole traffic stream on each link as one unit. Dealing with large road networks and broad geographic areas, they enable analysis of the large-scale performance of road networks. Microscopic models use the demand that is output from macroscopic models. They consider vehicles' characteristics separately, analysing time and distance headways for each vehicle and the usage of small road networks among other factors. Microscopic models allow for the presentation of actual traffic on streets, intersections, interchange configurations, intersection control processes, and even pedestrian movements. The mesoscopic level stands between both the micro- and macro- levels; bridging the inconsistencies between them. In mesoscopic models, traffic is considered in terms of platoons of vehicles as opposed to individual vehicles in microscopic models or as a stream of vehicles in macroscopic models. (Adebisi, 2017; ITE, 2014).

The calibration of microscopic simulation models is essential to account for the detailed interactions between vehicles in a network, and to model the congested locations intensively. In online models, calibration, heterogeneous driver behaviours, and traffic conditions are captured and simulated continuously by feeding in real-time field measurements, thereby replicating the actual state of traffic (Papathanasopoulou et al., 2016). Importantly, the demand and supply parameters are updated on a real-time basis to better reflect field conditions (Antoniou et al., 2009).

This paper presents a case study located in Egypt that focuses on the road network in the Cairo CBD area. In this area, traffic congestion plays a crucial role affecting all surrounding road networks. The study applies an online calibration framework and aims to validate microscopic simulation models.

The use of artificial intelligence facilitates numerous estimation and prediction problems. This is manifested in the use of ANNs for microscopic model parameters calibration (Ištoka et al., 2013). Results from this model show that ANNs is highly capable of calibrating microscopic model parameters, given measurable traffic indicators, such as travel time, queue length, the maximum number of vehicles stopping at the entrances of roundabouts, or a combination there of. On the other hand, the proposed algorithm application process has shortcomings represented in its time-consuming iterations needed to find the optimal set of parameters' values. It is therefore infeasible when used on a real-time basis for online models, where model parameters need to be calibrated quickly.

Other considerable research work has been done to calibrate microscopic traffic simulation models using various algorithms and heuristics, both online and offline. These approaches could be summarized in Trial and Error (TAE) (Hourdakis et al., 2003), Generalized least squares (GLS) (Toledo et al., 2004), Artificial Neural Networks (ANNs) (Ištoka Otković et al., 2013), Genetic Algorithms (Chiappone et al., 2016; Mathew & Radhakrishnan, 2010), Simplex Algorithm (Kim & Rilett, 2002), SPSA Algorithm (Zhang et al., 2008), and Transfer Function model (Qin & Mahmassani, 2004).

To calibrate such models, appropriate model parameters' values are determined based on measurable traffic performance indicators, such as the work of (Ištoka Otković et al., 2013) which calibrated the model parameters based on measurable performance indicators. In that research, a prediction function is generated using ANNs that estimates the performance indicators for any given set of model parameters' values. Then, the optimal set of parameters' values are extracted by performing many iterations of this prediction function, until it outputs performance indicators that match measured indicators in the field. The prediction function is generated in many cases for different types of traffic performance indicators including travel time, queue length, number of vehicles stopping at roundabout entrances, or combinations of these four indicators. Results have shown that using travel time on its own as a performance indicator generates better rates of prediction. Similar research work is performed by (Park et al., 2006), in which a network of urban streets consisting of 12 actuated signalized intersections is modeled and calibrated using ANNs. VISSIM and CORSIM microsimulation software was used for modeling. The calibration and validation procedures were performed based on travel time measurements and queue length at the studied intersections. The study results showed that the proposed algorithm could adequately calibrate the simulation models to replicate realistic network performance. Furthermore, for online model calibration tasks, prediction of network indicators, such as travel time, traffic flow, and average speed, must be available on a concurrent temporal basis. Yeon (2019) used recurrent neural networks (RNNs) for average speed prediction for 15 seconds (Shafqat et al., 2019) also used RNNs to predict short-term traffic flow.

This paper contributes to the existing literature by introducing a novel direct real-time calibration framework for microscopic simulation models using Multilayer Feedforward neural network (MFNNs). To the best of our knowledge, this is the first research which calibrates directly online the Vissim driving parameters' values, based on predictions of travel time and traffic flow on the network elements, thereby helping to produce parameter values that simulate the expected traffic conditions in the next time interval.

The two-step calibration procedure is considered significantly faster, and thus, more applicable for online models than the approaches followed in the literature which require time-consuming iterations for model calibration. Moreover, this research is the first to train combined AI models (i.e., Long-Short Term Memory based Recurrent Neural Networks (LSTM-RNNs) and Multilayer Feedforward neural network (MFNNs)) together, based on the driving behavior and traffic conditions during successive time intervals. Significantly then, the prediction of future traffic conditions is based on the traffic conditions of the past intervals and the current driving behavior.

The paper is divided into sections: Section 2 introduces the problem statement and describes the objectives. Section 3 presents the implemented methodology. Section 4 presents the results, and Section 5 concludes with the findings of this research.

2. Problem Statement

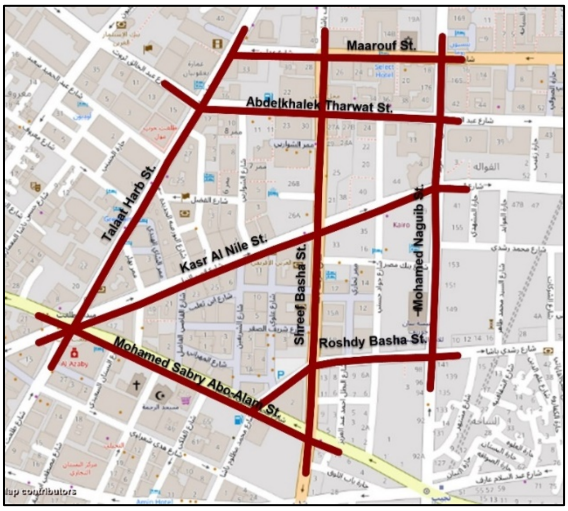

Fig. 1: Road network of the selected study area in Cairo CBD, Egypt

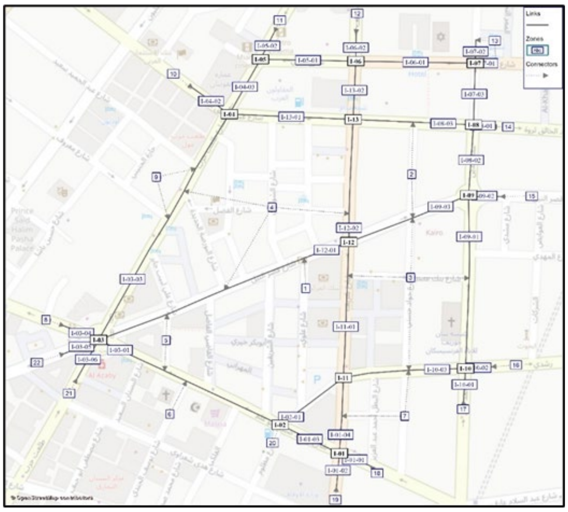

Fig. 2: Coded network of the study area

Traffic in greater Cairo is heterogeneous in terms of driving behaviour and mixed traffic composition. Drivers in a heterogeneous traffic system try to utilize any space available on any part of the road; regardless of the lanes and road rules, and in places where the network elements could be considered as below average. Pedestrians may cross at any location and at any moment. All these features are considered challenges for traffic modelers when trying to mimic prevailing field conditions and capture the heterogeneity of the driving behaviors in such countries (Papathanasopoulou et al., 2016).

The objective of this research is to develop an online calibration framework for a microscopic traffic simulation model in the Central Business District of Cairo (CBD) that consists of 8 corridors and 13 intersections (Fig. 1 and Fig.2). The road network features are successively signalized and non-signalized intersections so that the travel time including intersections delays can be evaluated.

The online calibration framework ensures that the traffic model can continuously replicate observed traffic conditions in terms of driving behavior. The microscopic level of traffic simulation is selected so that all interactions between vehicles and control infrastructure in the network can be represented.

3. Methodology

The research is conducted using the following steps: Starting from field data collection, dynamic OD matrix estimation is followed by microscopic modeling, sensitivity analysis, and finally production of the calibration framework using Artificial Neural Networks (ANNs) occurs.

Several types of data are required in this stage of network coding. Traffic Volume Data are collected via manual classified traffic counts on the AM peak period. Signal timing and phasing data are collected at all intersections. The calibration process of the simulation model requires a measure of goodness upon which the quality of calibration can be evaluated. Travel time data on links are collected using Google API and Python programming tools that can collect such information on a predefined regular basis network links represent each homogenous section of a road (102 links), and nodes represent the points of links intersections (45 nodes) are modeled in the macroscopic traffic model.

It is considered that traffic count data is insufficient to infer a unique OD matrix for a transportation network, because they lead to a list of underdetermined equations which may give numerous origin-destination matrices that replicate the given traffic counts on links. That is because the counted objects are always significantly smaller than the number of origin-destination pairs. Various additional assumptions and *a priori* information about the travel pattern can guide the calculation to reach a unique solution (Cascetta, 1984; Cremer & Keller, 1987).

In this research, as no data are available about any outdated OD matrix for the study area, a process of estimating an

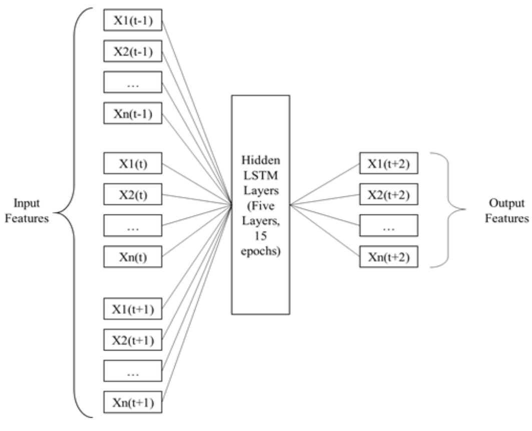

Fig. 3: Structure of LSTM ANNs

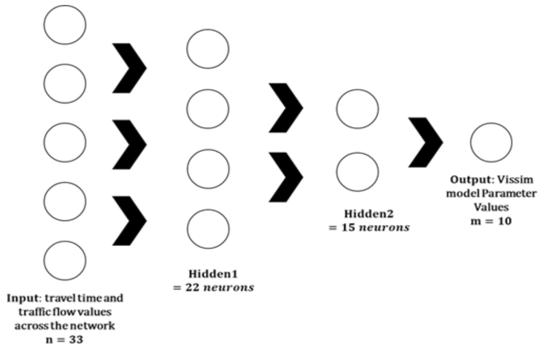

Fig. 4: Structure of MFNNs

initial OD matrix is performed using a best-guess approach based on field observation and the author's experience of travel patterns. The travel pattern between all OD pairs in the study area is translated into the estimated initial OD matrix.

Given the initial OD matrix from available information and assumptions, the estimated origin-destination matrix is then inferred by minimizing the deviation between link volumes from traffic counts, and the estimated link volumes from the estimated origin-destination matrix. This process is iteratively repeated until reaching satisfactory results. While estimating the target OD dynamic matrices, based on this initial OD matrix and the traffic counts, the pattern of the initial matrix is retained as the same.

Dynamic OD matrices estimation is performed using the traffic volumes for each time step of analysis (30 minutes). The process of demand matrix estimation and correction is achieved using the "Least Squares" method inside PTV Visum demand modeling (PTV Planung Transport Verkehr AG, 2017).

PTV Vissim software takes into consideration several constraints of lane distribution, vehicle type composition, and signal control which helps in analyzing and testing the interactions between systems in the road network, such as adaptive signal control and route recommendation (PTV Planung Transport Verkehr AG, 2018). Vissim is used to apply the proposed calibration framework. Geometric network characteristics and features are coded into the model, such as the network links' geometry, traffic control types at intersections, priority rules and reduced speed areas, traffic flow values, and routing decisions.

Default values of driving behavior parameters from the Vissim manual are initially used. Initial performance verification and error checking of the developed model are performed to evaluate the model. Vissim models have multiple driving behavior parameters that need to be calibrated. It is also necessary to perform a sensitivity analysis to identify which parameters are effective to save

Table 1: Traffic volume Data for the Study Area (vehicles/hr/lane)

Approach Code	Time Interval 7:30 to 8:00 AM	10:00 to 10:30 AM	Approach Code	Time Interval 7:30 to 8:00 AM	10:00 to 10:30 AM
I-01-01	94	68	**I-06-01**	323	234
I-01-03	162	118	**I-06-02**	278	202
I-01-04	124	90	**I-07-01**	225	163
I-02-01	795	577	**I-07-03**	166	120
I-03-01	173	125	**I-08-02**	290	211
I-03-03	470	341	**I-08-03**	460	334
I-03-06	314	228	**I-09-01**	405	294
I-04-02	338	245	**I-09-03**	304	220
I-04-03	544	394	**I-10-01**	364	264
I-05-01	405	294	**I-10-03**	177	128
I-11-01	282	205			
I-12-01	406	294			
I-12-02	231	168			
I-13-02	253	183			

Table 1: Mean Travel Time (sec.) on Different Paths

Path code	Time Interval 7:30 to 8:00 AM	10:00 to 10:30 AM	Path code	Time Interval 7:30 to 8:00 AM	10:00 to 10:30 AM
Path1	168	205.0	**Path5**	193	291.0
Path2	107	144.2	**Path6**	67	89.5
Path3	101	132.7	**Path7**	82	95.0
Path4	123	181.2	**Path8**	63	63.3

simulation and computational processing burdens. The Analysis of Variance (ANOVA) test is utilized to identify Vissim significant model parameters to be calibrated. Artificial Neural Networks (ANNs) are used to build a prediction function that can estimate the values of these parameters so that when they are used in the model, it produces results that mimic actual observed behavior. The role of the ANNs is to figure out the relationship between driving behavior parameters and the model's performance so that the ANNs can be used as an estimator for the driving behavior parameter values when using actual field observations.

The ANNs model is trained using a generated dataset from the model. To build such a dataset, it is necessary to input a large set of parameters values combinations and run the simulation model. 1000 combinations of model parameters were calculated using Latin Hypercube Sampling (LHS) technique, which is a stratified random sampling technique that ensures taking samples from identified parameter ranges, while maintaining all possible combination cases covered. The output model performance measures are collected from the simulation model. Both input and output data constitute the training and validation database to be used in building the ANNs model.

ANNs models are implemented in a two-step framework. In the first step, long-short term memory based recurrent neural networks (LSTM), with five hidden LSTM layers and 15 epochs (Fig. 3), are used to predict travel time and traffic flow for a 30-minute time interval based on the previous five-time intervals. In the second step, multilayer feed-forward neural networks (MFNNs), with a number of two hidden layers with 22 and 15 neurons in the first and second layers respectively (Fig. 4), perform the direct estimation of Vissim driving behavior parameters based on predicted travel time and traffic flow values from Step 1.

The output-calibrated parameters are then used in the simulation model, and the model travel time results are compared with the values fed into the LSTM model, before being compared with the actual values of travel time collected using the online tool. Therefore, the two steps

Table 2: Final Set of Significant Model Parameter

N	Input Parameters	F-Statistic	F critical	Significance
P1	Min Look Ahead Distance - m	4.01	2.46	True
P2	Number of Interaction Objects	434	2.46	True
P3	Average Standstill Distance - m	208	2.46	True
P4	Additive part of desired safety distance (Wiedemann 74) - m	180	2.46	True
P5	Multiplicative part of desired safety distance (Wiedemann 74) - m	63	2.46	True
P6	Waiting Time Before Diffusion - sec	13	2.46	True
P7	Safety Distance Deduction Factor	14	2.46	True
P8	Collision Time Gain - sec	52	2.46	True
P9	Lateral Distance Standing - m	142	2.46	True
P10	Lateral Distance Driving - m	100	2.46	True

together constitute a framework for traffic volume and travel time prediction and the calibration of Vissim driving behavior parameters on a real-time basis.

4.0 Results

4.1 Data Collection Results

Tables 1 and 2 present the field survey data of traffic volume and the average travel time on each path, respectively. These tables provide the average of collected traffic data on 30 minutes time periods. The first period starts from 7:30 to 8:00 am while the last starts from 10:00 to 10:30 am.

4.2 ANOVA Test Results

Table 3 summarizes the final set of significant model parameters, identified by ANOVA test, which will be used in the calibration procedure, where 10 parameters are identified to have a significant effect on the simulation output at an alpha level of (0.05), and critical F-statistic threshold is (2.46).

4.3 Traffic Volume and Travel Time Prediction Results

Recurrent Neural Networks resulted in a good prediction ability for travel time and traffic volume based on inputs from previous time steps. The evaluation was completed using the GEH formula, which measured the closeness of the values between LSTM model predictions and actual field measurements of traffic volume. LSTM results show that it is applicable to predict traffic volume values on the network that match actual values in the field. For the testing dataset, the GEH value is less than 5.0 for 99% of the network links. This is accepted by the rules of the FHWA, where 85% of the network links must have GEH values less than 5.0 (Kelton & Law, 1991). Figure 5 shows the training and validation of travel time prediction results.

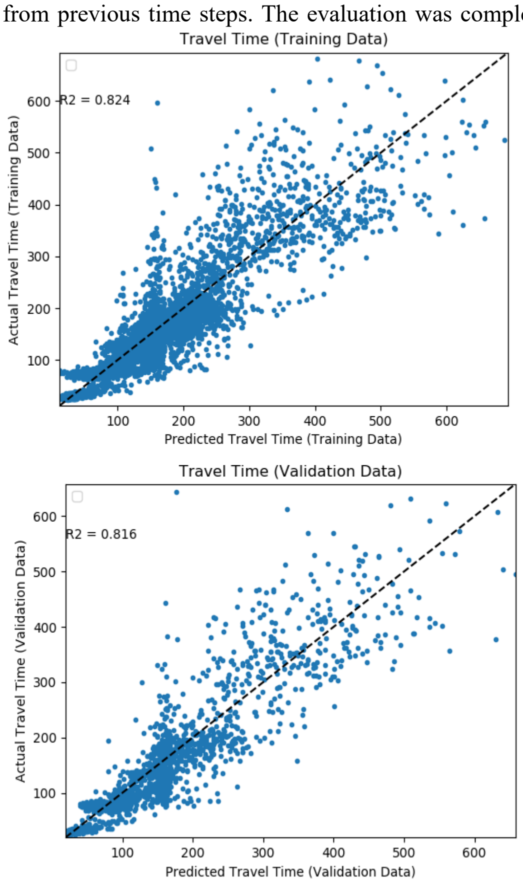

Fig. 5: Training and validation results of Travel Time prediction

4.4 Vissim Parameter Values Estimation Results

Figure 6 shows the results of Multilayer Feed-Forward Neural Networks (MFNNs) functionality for the model training dataset. As shown, the correlation between MFNNs and Vissim results is (0.657). Besides, Figure 7 shows the correlation using the testing dataset (0.654). This level of accuracy can be considered sufficient due to the stochastic nature of the traffic stream itself. The developed algorithm will be self-improving by continuously learning from field data when put into actual operation. The introduced algorithm directly estimates the model parameter values in less than a second without time-consuming iterations, which makes it applicable for calibrating online simulation models of road networks.

4.5 Test Application of the Proposed Framework

The framework is applied for online estimation of Vissim model parameter values based on five previous time steps of travel time data. Table 4 gives the predicted travel time by the framework versus actual measured travel time with a correlation coefficient of 0.9. This shows the powerful ability for RNNs to replicate observed travel time patterns and estimate future values based on it. This table also shows a comparison between actual measured and

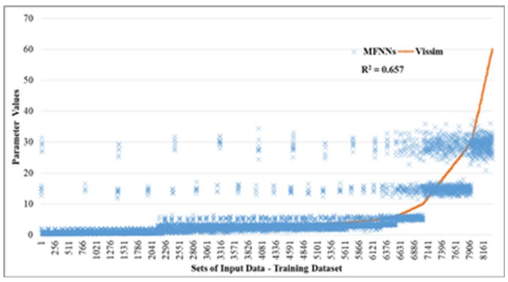

Fig. 6: Training results of Vissim Model Parameters

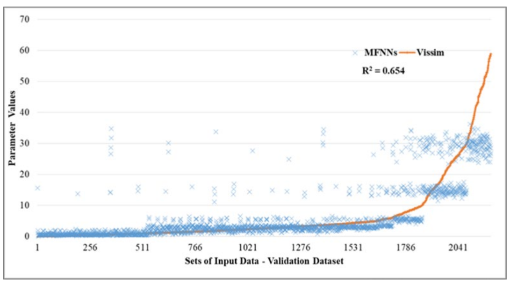

Fig. 7: Validation results of Vissim Model Parameters

simulated travel times where the correlation coefficient is 0.75. As such, the proposed framework showed a good ability to produce simulated travel times. Table 5 shows the results of the parameters' value estimation, which will be used in the Vissim model and in which the resulted travel times will be recorded.

Table 4: Comparison between LSTM, Vissim, and Actual Field measurement of Travel Time

Path	Time Step 6 Travel Time		
	Estimated Values By LSTM	Vissim Model Values	Actual Values
Path1	204.9	187.7	205.0
Path2	144.0	255.4	144.2
Path3	133.0	95.0	132.7
Path4	181.0	170.4	181.2
Path5	291.0	291.7	291.0
Path6	90.1	71.5	89.5
Path7	95.0	80.8	95.0
Path8	63.0	32.5	63.3
R^2 *	0.99	0.75	-

* Compared to Actual Values

4. Conclusion

The paper introduces a framework for online calibration of microscopic model parameters and applies it to the CBD area in Cairo. The research work concerns capturing the effect of dynamic changes in driving behaviour as a response to changes in traffic conditions on the traffic flow characteristics in the CBD. Again, driving behaviour parameter calibration is essential in the overall calibration process as it controls the overall behaviour of the modelled objects. The calibration process is based on calibrating the effective Vissim driving behaviour parameters given measurable traffic indicators from the field.

To identify significant model parameters, network modelling and sensitivity analysis using ANOVA test is performed. Therefore, the calibration process is performed using a two-step framework utilizing Artificial Neural Networks. In the first step, short term traffic volume and travel time are predicted across the network on a real-time basis given historical patterns. In the second step, these estimates are used to calibrate Vissim driving behaviour parameters to mimic actual field conditions. In this proposed framework, the parameters calibration procedure is performed directly using the travel time and traffic volume across the road network. As such, this calibration methodology is considerably faster than other time-consuming processes mentioned in the literature, which require many iterations until eventually finding the optimal parameter values.

Results show that the proposed framework can perform the required tasks with a good level of accuracy. Regarding the framework's first step, the predicted short term travel time and traffic volume could be validated with an R2 of (0.816). This is considered a good accuracy given all the uncertain and stochastic nature of the observed travel time and traffic volume. Regarding the second step, the calibration procedure can mimic travel time observed on the field with an R2 of (0.654). This is considered on the other hand a plausible result comparing to the intelligence of the calibration process.

Table 5: Estimated Parameter Values by the Framework

Code	Parameters	Default (min-max)	Estimated Parameter
P1	Min Look Ahead Distance - m	10 (1-20)	20.32
P2	Number of Interaction Objects	2 (0-4)	3
P3	Average Standstill Distance (Wiedemann 74) - m	2(1-5)	3.59
P4	Additive part of desired safety distance (Wiedemann 74) - m	2(1-5)	3.29
P5	Multiplicative part of desired safety distance (Wiedemann 74) - m	3(1-6)	4.09
P6	Waiting Time Before Diffusion - sec	60(0-60)	37.87
P7	Safety Distance Reduction Factor	0.6(0-1)	0.63
P8	Collision Time Gain - sec	2(1-10)	6.85
P9	Lateral Distance Standing - m	1(0-5)	1.79
P10	Lateral Distance Driving - m	1(0-5)	0.69

Finally, the overall results of this research show that ANNs can be effectively used to calibrate online traffic simulation models. However, other modifications to the calibration procedures or the ANNs models' structures are required to improve the calibration accuracy and better produce models that more accurately mimic reality. Thus, it may be used to enhance the estimation capabilities for current road network conditions. Furthermore, generating proactive traffic management schemes could be a potential extension for this work.

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Keywords

VISSIM, traffic simulation, Cairo traffic, urban traffic simulation, driving behaviour model.

Network Planning versus Corridor Implementation in the Western Balkans Region

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Abstract

The present paper focuses on the problem of missing transport links in the Western Balkans. A brief description of the political background is followed by an indication of the poor state of the region's transport infrastructure. There are two main approaches to solving these infrastructure problems and improving the provision of transport in the region. These are described as the "Corridor approach" and the "Network approach". The analysis evaluates the benefits of each approach and makes suggestions for the future.

1. Problem Statement – Transport in the Western Balkans

The term "Western Balkans" refers to the following six countries: Albania, North Macedonia, Serbia, Montenegro, Bosnia and Herzegovina, and Kosovo. To understand the region's transport problems, some political background is needed. Below is a brief account of the relevant key points.

In 2014 the political leaders of the Western Balkan countries met for the first time in Berlin under the term 'Western Balkans Six '(WB6). The aim of the meeting was to bring a new dynamism to regional cooperation by building and connecting transport and energy infrastructure as one of several drivers for growth and employment. This "Connectivity Agenda" was not only designed to improve links among the Western Balkan countries, but also with the member countries of the European Union. Significantly, the agenda has received EU endorsement and support from the outset. In more precise terms, an indicative extension of the Trans-European Transport network (TEN-T) in the Western Balkans, including the core network, the core network corridors and pre-identified priority projects has been defined since 2017. Extending the TEN-T core network corridors to the Western Balkans ensures better integration with the EU as well as a basis for leveraging investment in infrastructure projects, such as gaining EU support through the Western Balkans Investment Framework (WBIF) and the Connecting Europe Facility (CEF).

Improving connectivity within the Western Balkans, as well as between the Western Balkans and the European Union, is a key factor for growth and employment. It will bring clear benefits to the region's economies and citizens. However, it is not only infrastructure that will enhance connectivity. The implementation of technical standards and soft measures, such as aligning and simplifying border crossing procedures, railway reforms, information systems, road safety and maintenance schemes, railway unbundling, and third-party access are also highly important and should not be ignored.

In 2017, the EU along with the countries of the Western Balkans agreed on the establishment of a "Transport Community" between them. The key objective was the deeper integration of the Western Balkan region with the EU transport market through the implementation of common standards, network efficiency, and improved quality of service offered to citizens and businesses. More specifically, connectivity implies focusing on investments that improve transport systems and their infrastructure, which in turn strengthens the countries' competitiveness. Additionally, infrastructure projects contribute to building metaphorical bridges in the region, fostering positive neighbourly relations that support peace and reconciliation.

2. Trans-European Transport Network (TEN-T)

A direct consequence of the political approach was the extension of the European TEN-T planning into the Western Balkans region. TEN-T is the result of the EU task to build a modern integrated transport system that strengthens the EU's global competitiveness. It should also be able to meet the challenges linked to sustainable, smart, and inclusive growth. The first step towards this goal is ensuring a well-functioning infrastructure that can transport people and goods efficiently, safely, and sustainably. Today, the EU's physical infrastructure counts over 217,000 km of railways, 77,000 km of motorways, 42,000 km of inland waterways, 329 key seaports and 325 airports. Through the Trans-European Transport Network policy, the EU aims to build an effective EU-wide transport infrastructure network. EU funding programmes and initiatives make financial support available to the projects implementing the TEN-T.

As a follow up to various high-level conferences and meetings, EU leaders and the Prime Ministers of the Western Balkans gathered in Brussels on 21 April 2015. They adopted a Joint Statement to reaffirm their commitment to connectivity, good neighborly relations, regional cooperation, and European integration. In this Statement, the extension of the TEN-T to the Western Balkans region was agreed upon. (Western Balkans 6 meeting in Brussels, 2015). Following legal action by the EU, the TEN-T Regulation today includes maps indicating a general layout of the future multimodal transport network in the Western Balkans. (Connectivity Agenda, 2015)

In 2017, the EU decided to extent the concept of the "core Corridors" also to the region of the Western Balkans. (REGULATION (EU) No 1316/2013, 2013). It should be highlighted that the Corridors' concept, in the meaning of the 1316 Regulation, has to do rather with financing than pure transport planning. In this respect, as far as transport is concerned, lists of projects along priority corridors have been identified. These projects form the core of the transport infrastructure needs of the region that the EU could co-finance. The main instrument in this effort is the 'Western Balkans Investment Framework' (WBIF), which is a regional blending facility supporting EU enlargement and socio-economic development in Albania, Bosnia and Herzegovina, Kosovo, Montenegro, North Macedonia, and Serbia.

The WBIF was established in 2009 as a joint initiative of the European Commission, the Council of Europe Development Bank, the European Bank for Reconstruction and Development, the European Investment Bank, and several bilateral donors. The World Bank Group, the KfW Development Bank and the AFD (Agence Française de Développement) subsequently joined the Framework. Accordingly, over the past 10 years, the transport sector in the Western Balkans has received considerable investment.

Despite such backing, a Regional Balkans Infrastructure Study - Transport (REBIS) concluded that 30% of the region's comprehensive road network requires immediate maintenance and/or upgrade. It also identified capacity constraints on more than 30% of the rail network and stressed the urgent need for rail rehabilitation and maintenance. In 2015, the Western Balkans' leaders agreed on the Core Transport Network for the region and the indicative extension of the EU Core Network Corridors in the Western Balkans. This will enhance connectivity within the region and between the region and the EU. The South-East Europe Transport Observatory (SEETO) has estimated priority projects' costs at €13.9 billion, while the Vienna Institute for International Economic Studies found that such a package could boost regional GDP growth by up to one percentage point per year over 15 years and help create more than 200,000 jobs.

The signing of the Transport Community Treaty in 2017 encourages better planning of transport investments and procedural streamlining. The new 'Transport Community Secretariat' (TCS) is based in Belgrade and replaces SEETO.

3. Which Approach? Network Planning Versus Corridor Implementation

Since the WBIF continues to provide grants to prepare and build projects, the key question is not whether projects can be funded, but which approach to the development of transport in the Western Balkans should be considered optimal. This issue could be raised otherwise as follows:

- Should the principal goal be the rapid construction of a transport corridor that would link the main cities of the Western Balkans with the EU to strengthen the growth of the connected poles?
- Or should the main goal be the regional development of the area; with the aim of spreading the relevant social, political, and wider economic benefits to throughout the region?

The term "network" refers to the framework of routes within a system of locations, identified as nodes. A route is a single link between two nodes that are part of a larger network which can refer to tangible routes such as roads and rail lines, or less tangible routes such as air and sea corridors. (Rodrigue et al, 2018).

Alternatively, if we use the terminology of classic Ekistics (Doxiadis and Papaioannou, 1974, p.9):

> a network can be described as the natural and man-made connective system which serves and integrates settlements, such as roads, water supply and sewerage systems, electrical generating and distribution facilities communications facilities, and economic, legal, educational, and political systems.

On the other hand, a transport corridor specifically determines the routes, transport nodes, and their access links that accommodate linear transportation of passengers and freight. In its policy, the European Union provides that corridors are an instrument to facilitate the coordinated implementation of networks (REGULATION (EU) No 1316/2013, 2013).

The EU transport policy currently includes strategies to realize the internal market, and further develop a trans-European network together with major transport corridors aiming at a better-connected Europe. However, there are many reasons to differentiate a network strategy from a corridor strategy. Expected economic impacts have a concrete role in the process. When examining the motivations and reasons for a Network or a Corridor, one may distinguish the varying goals to be met with the application of each of the two alternatives.

An effective transport network aims at realizing a final goal that could satisfy all political, economic, and social expectations of a region. Safety, interoperability, speed and comfort in a network of adequate density can safeguard the best conditions for high level passengers' movements, as well as efficient freight movements. On the other hand, the main advantage of a corridor is usually the simplicity in its operation. The operators of a corridor can establish several mechanisms for the refinement of its function, such as efficient governance ("one-stop-shop" can be a good example of efficient governance), and many other cooperation tools to overcome problems like border crossings, etc. The lack of alternatives in the connection is the most important problem in the operation of a corridor. Any consideration of the problem should look seriously into the economics of the region and the business case for the project. Indeed, the transport sector is an important component of the economy and a common tool used for development. High density transport infrastructure and highly connected networks are commonly associated with high levels of development. When transport systems are efficient, they provide economic and social opportunities and benefits that result in positive effects including better accessibility to markets, employment opportunities, and additional investments.

The present paper elaborates on the various factors that may describe the study problem, such as the political situation of the region, economic scarcity, availability of funds, etc. The existing infrastructure will be described and the parameters that the EU takes into consideration for planning the "new" TEN-T after 2024 will be examined.

4. Preliminary Results

The analysis of the optimum strategy for the transport development in the Western Balkans should concentrate on an approach that would ensure the compliance with a wide variety of parameters as follows:

For the whole transport system

- Administration building to eliminate all operational barriers
- Integration among transport modes (inter-modality)

For railways

- Measures to achieve safety and interoperability

For roads

- Increase of capacity - elimination of bottlenecks along critical sections

Air and maritime

- Increase of technical and administrative capacity

The realization of transport infrastructure, especially in the region of the Western Balkans where there is a significant delay in investments on transport, is based on the existence of proper financing. As a first step, a project list must be proposed, which should have the acceptance of the States of the Western Balkans. Then, the involvement of the interested International Financial Institutions (IFIs) should be ensured to safeguard a smooth financing curve for at least 10 years.

This strategy would allow reaching the targets set by the EU and the Western Balkans States for 2030.
Nevertheless, two main issues related to the Western Balkans planned projects should be considered:

- Firstly, the foreseen end date of several planned projects is unknown, mainly due to uncertainties over the financing sources. In these cases, 2030 has been assumed as the expected completion date.

- Secondly, the expected impacts of the projects on the infrastructure technical parameters must be clearly defined.

Today, the building of the Western Balkans infrastructure is based on a strategy that foresees the realization of Corridors, and the main reason is the lack of sufficient financing.

- The creation of one main Corridor is a first priority: Extension of the Orient-East Corridor/OEM into the Western Balkans territory. (European Commission DGMOVE, December 2017)
- A second priority is the creation of a second Corridor: the Mediterranean Core Network Corridor. (European Commission DGMOVE, January 2018)

Both Corridors are important for the region, but the main goal to develop a balanced transport network in the whole area of the Western Balkans is put on hold. That is, for at least 10-15 years the main goal of creating the proper transport environment needed to achieve the critical parameters mentioned above will remain secondary.

An in-depth analysis of the consequences of this strategy would underline a number of results that might have serious consequences for the global development of the region. The results would naturally show that any planning decision focusing solely on the construction of one or two transport Corridors linking the region of the Western Balkans with Central and Western Europe will have mainly monetary benefits for the latter. The orientation of this strategy towards freight movements will result in sufficient rates of profitability, as infrastructure of lower standards and cost will serve large volumes of goods. On the other hand, more costly solutions that will create a complete transport network in the region of the Western Balkans will serve the wider economic and social needs of the region, by contributing to the smooth development of the global economy promoting efficient trade, passengers and freight movement, environment, etc.

5. **Conclusion**

The main conclusions of this paper are as follows:

Transport is a principal factor for the economic development of the area, at both microeconomic and macroeconomic levels. It also has important social effects, which should not be ignored.

A strategy that directs the investments to projects which aim solely at building transport corridors can be effective from a monetary point of view (as it promotes "bankable" projects), however it neglects the fundamental needs of the region.

The "bankability" of projects along a main transport corridor can be considered as most likely because they refer to (a) high transportation volumes (mainly international and transit) but also (b) to freight transportation, that can be served with infrastructure of lower quality.

Other projects, such as city bypasses, connections of main nodes within the territory of the Western Balkans (not serving international flows), construction of a safe secondary road network, are not - for the moment at least - eligible for international funding in the context of the today's strategy.

The goal of the development of a complete transport network as a first priority would have considerable positive impacts, such as:

- Creation of routes enabling new interactions between economic entities in the region.
- Improvements in the time performance, notably in terms of reliability; this would be a major improvement of the quality of passenger transport, also implying a better utilization of existing transportation assets.
- Access to a wider market range where economies of scale in production, distribution and consumption can be improved. Increase in productivity from the access to a larger and more diverse base of inputs (raw materials, parts, energy or labor) and broader markets for diverse outputs (intermediate and finished goods).

In this paper we have addressed the question of which approach would be optimal for the region of the Western Balkans. Given the above analysis, we may conclude that an appropriate strategy for the promotion of projects for the development of a complete network, together with the development of transport corridors, would be a better solution for both its economy and societies. It is evident, however, that the strategy of developing transport corridors alone, while neglecting other important projects is more feasible for the decision-makers of the EU. Further, we must also take into consideration "western" interests and the monetary effectiveness of this strategy for the International Financial Institutions that have the financial burden of this strategy.

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Keywords

Western Balkans; EU Transport Policy; Trans-European Transport Network (TEN-T); Network planning; Corridor development; social needs; monetary effectiveness

Considerations for an Outbound Direction Bus Lane in an Urban Area

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Abstract

This paper examines the feasibility of inserting a new exclusive bus lane in the public transport network of an urban area. It gives data and a case study example that demonstrate how a bus lane can be evaluated especially how a bus lane of a relatively limited length and of a relatively low bus frequency is worth being implemented – normally - in the case of a one-way street connecting the city center with the suburbs. The approach followed, analyses the findings from a case study in the eastern part of Thessaloniki, the second largest city in Greece with a population of approximately one million inhabitants. The bus lane used as the case study is focused on an outbound direction along a one-way street that connects the city center with the eastern suburbs of the city. This bus lane operates during part of the day according to the traffic conditions and the demand needs along the road corridor where it is located. The analysis includes field measurements of traffic data along the bus lane as well as a questionnaire-based survey that was mainly focused to investigate the quality of the service as perceived by the passengers. The paper shows that such bus lane can be fully justified (though with a reduced number of buses per hour), in terms of the travel time savings that it provides, the uninterrupted bus flow operation that it provides (that minimises the time they spend on the bus) and other characteristics. Parking restrictions and other traffic regulations enforcement is, however, necessary to prevent violations by drivers of private cars and minimise any adverse effects on the bus lane's operation.

1. Introduction

The environmental impact of traffic is a major problem globally. Authorities in the European Union (EU) are trying to reduce its impact through the design and implementation of sustainable urban mobility plans (SUMP). According to the New Urban Agenda, adopted at the United Nations Conference on Housing and Sustainable Urban Development (Habitat III) in Quito in 2016, there is a commitment (Goal 36) to "promoting appropriate measures in cities and human settlements that facilitate access for persons with disabilities, on an equal basis with others, to the physical environment of cities, in particular to public spaces, public transport" (United Nations, 2016). Another commitment (Goal 114) refers to "a significant increase in accessible, safe, efficient, affordable and sustainable infrastructure for public transport" among other actions. Clearly, the role of public transport is fundamental to achieve the UN goal of global sustainable urban development (United Nations, 2016).

Although an efficient transport system can reduce traffic congestion (Dirgahavani, 2013), air pollution, energy consumption (Liu et al., 2017), and carbon footprint (Aggarwal & Jain, 2016), a competitive public transport system is also needed to combat congestion (Dahlström, 2002). Accordingly, to reduce reliance on private vehicles, decision-makers attempt to promote environmentally friendly transport modes such as cycling, walking, and public transport systems. Rosenberg (1984) has noted that random movements in which "people form into lanes and as they are picked up by buses or cars, (…) their places may be taken by more people coming out of buildings". Given this microlevel congestion, establishing efficiencies in the smooth operation of urban public transport systems becomes imperative.

To increase public transport usage, priority measures should be implemented to make systems more attractive compared to the use of private cars (Basbas, 2009). The implementation of bus lanes is one efficiency measure to ensure bus priority which makes public transport more competitive (Kim, 2003). Bus lanes can be created at low cost and in a relatively short period of time. They are therefore considered to be a cost-effective way to make public transport more efficient (Deng & Nelson, 2011). Another measure to improve the bus system is to convert the conventional bus service into a Bus Rapid Transit (BRT) system. This option has been successfully implemented in many countries around the world (Vincent, 2010) (Tiwari & Jain, 2010). The operation of bus lanes and BRT systems provides multiple benefits and is therefore crucial for managing the urban environment. It must be mentioned, however, that the successful operation of a bus lane depends on effective enforcement to prevent disruption caused by violations such as unauthorized use or illegally parked vehicles (Basbas, 2007).

Bus lanes come in several types; kerbside unsegregated bus lanes, segregated bus lanes, offset unsegregated bus lanes, median unsegregated bus lanes (Mundy, Trompet, Cohen & Graham, 2017), contra-flow bus lanes (Stamos, Kitis & Basbas 2013), inbound direction and outbound direction bus lanes among others, and are usually characterized by their length. Often, local conditions require a shorter bus lane as the benefits outweigh the cost. This could be due to high levels of congestion in small road segments, for example. Local authorities must then implement bus lanes to enable buses to save valuable time. In many cases, planners must take measures to minimize delays experienced by users of the public transport system, even if these measures only apply specifically to a small area and are not part of a greater network plan.

This paper attempts to demonstrate how such bus lanes can be evaluated and in doing so, to answer the question of whether an outbound direction bus lane of a relatively limited length and of a relatively low bus frequency is worth being implemented in a one-way street connecting the city center with the suburbs. That is, we seek to answer the following question: Do passengers appreciate the small time gains from such arrangements?

Our approach is to analyse the findings from a case study that focused on an outbound direction bus lane implemented along a one-way street in the eastern part of Thessaloniki, the second largest city in Greece with a population of approximately one million inhabitants. Although a metro is currently under construction in the central and eastern part of the city, for the time being buses remain the only available public transport. The bus lane being studied connects the city center with the eastern suburbs of the city and only operates during certain hours of the day. The analysis was based on field counts along the bus lane in question. In addition, a questionnaire-based survey was used to investigate the quality of the service as perceived by the passengers.

2. Methodology

The kerbside unsegregated bus lane under consideration is located on the right side of Georgiou Papandreou Street, a one-way arterial street carrying traffic from the city center to the eastern suburbs. The bus lane is 644m long and operates for 9 hours on weekdays from 12:00 noon to 9:00 pm. There are three bus stops along its entire length. Since most bus lanes in the city are inbound, it was considered interesting to evaluate an outbound bus lane and explore whether such a measure is worth implementing more widely across the city. Another element worth examining, considering its short length, was its performance against other bus lanes in the city. Six bus lines utilize this bus lane (No.5, 6, 8, 30, 33, 78). Three out of the six lines (No.5, 6 and 8) are characterized by high demand. Nevertheless, it should be noted that the bus lane only serves 20 buses per hour; and while there are various recommended thresholds around the world, the Los Angeles Metropolitan Transportation Authority, for example, generally implements bus lanes which serve a minimum of 25 buses during peak hour period (Litman, 2016).

The field data collection occurred during the periods of March-May 2015, November 2015, and September-October 2016. Field work consisted of recordings (directions, number of lanes, horizontal and vertical traffic signs, location of traffic lights, etc.; field counts (bus travel time, passengers' waiting time at a bus stop, traffic volume, parking supply and demand in the impact area of the bus, illegal parking on the bus lane etc.); and a questionnaire-based survey (300 interviewees) addressed to passengers at one of the three bus stops of the bus lane.

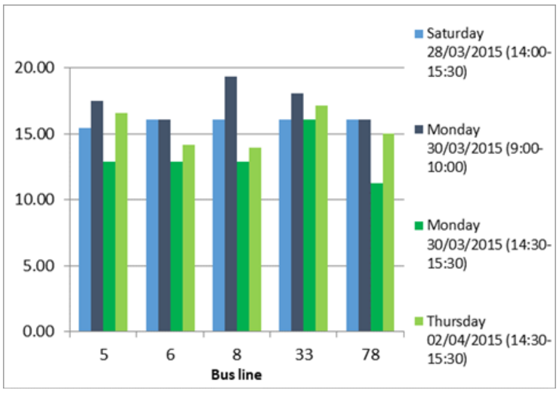

Fig. 1: Average speed (km/h) per bus line

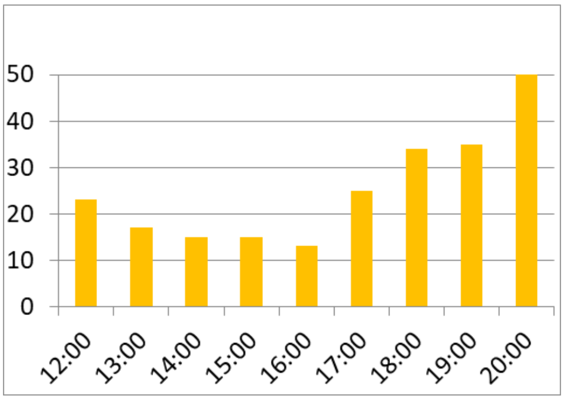

Fig. 2: Time period of illegal parking in the bus lane

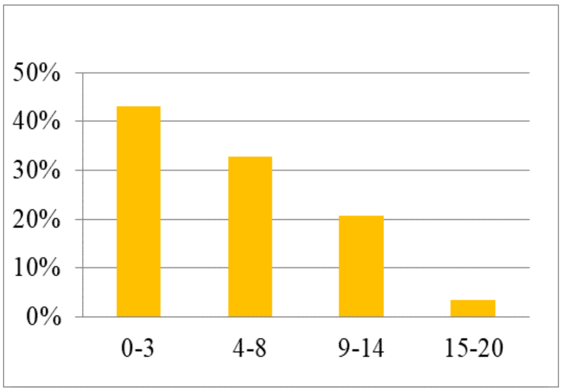

Fig. 3: Distribution of the passengers' observed waiting times (in minutes) at bus stops along the lane

3. Results and Discussion

One of the gravest problems affecting the operational characteristics of the bus lane is illegal parking; especially when considered in relation to average bus speeds. In the impacted area of the bus lane, it was found that demand for parking exceeds supply: whereas demand was estimated to be 2717 parking spaces, the supply was calculated to be only 1727 spaces or approximately 63.5% of demand.

The average speed of the buses using the bus lane is shown in Fig. 1. On average, this speed is just below 15 km/h, which, when compared to the average speed observed in other bus lanes in the city is approximately 12-15% lower. More specifically and taking into consideration the total length of each bus route, the average speed of buses in bus lanes in other parts of the city is as follows: line 5-17.31 km/h, line 6-17.21 km/h, line 8-16.66 km/h, line 33-18.33 km/h and line 78-21.12 km/h (The Organization of Urban Transportation of Thessaloniki, 2016). The relatively higher speed of line 78 can be explained by the fact that it connects the city airport to the intercity bus station, and therefore has special operational characteristics. This detail notwithstanding, it should be noted that, following the implementation and operation of bus lanes in the city of Athens, the average speed of buses using bus lanes increased to 23km/h (Athens Public Transport Organization, 2020).

As regards the number of illegally parked cars along the bus lane, Fig. 2 shows the numbers found during the different hours of the day. Drivers tend to violate the bus lane more during the afternoon period, when they return home, something which was predicted due to the residential character of the area. Also, the passengers' observed waiting time (in minutes) was measured at the bus stops and this is presented in Fig. 3.

Table 1: Descriptive statistics of the bus lane's evaluation by the passengers

Description	Coding	Percentage (%)
Gender	0: Male,1: Female	0: 49, 1: 51
Age	0: 18-24, 1: 25-39, 2: 40-54, 3: 55-64, 4: ≥65	0: 20, 1: 20.7, 2: 27.3, 3: 18.3, 4: 13.7
Area resident	0: Yes, 1: No	0: 52.7, 1: 47.3
Car availability	0: Yes, 1: No	0: 72.3, 1: 27.7
Main user of the private car	0: Yes, 1: No, 2: Non-car holder	0: 42.7, 1: 29.7, 2: 27.7
Frequency of Public Transport use (minutes)	0: 0-10, 1: 11-20, 2: 21-40, 3: 41-60, 4: >60	0: 21.3, 1: 18, 2: 27, 3: 18.3, 4: 15.3
Knowledge of the existence of the bus lane	0: Yes, 1: No	0: 94.3, 1: 5.7
Bus usage in this road axis before the implementation of the bus lane	0: Yes, 1: No, 2: Ignore the existence of bus lane	0: 74.2, 1: 20.4, 2: 5.4
Perceived waiting time at the bus stop (minutes)	0: 0-3, 1: 4-7,2: 8-12, 3: 12-16, 4: >16	0: 4.3, 1: 26.7, 2: 42.3, 3: 18, 4: 8.7
Number of busstops along the on-board travel distance as stated by the interviewees	0: 1-5, 1: 6-10, 2: 11-17, 3: 18-24	0: 20.3, 1: 51.3, 2: 15, 3: 13.3
Improvement in travel time (minutes)	0: 0-3, 1: 4-7, 2: 8-12, 3: >12, 4: No improvement or ignore of existence of the bus lane.	0: 8.7, 1: 16.4, 2: 12.4, 3: 9.4, 4: 53.2
Walking time to the bus stop (minutes)	0: 0-3, 1: 4-6, 2: 7-10, 3: 11-15, 4: >15	0: 43, 1: 34.3, 2: 18, 3: 3.7, 4: 1
Optimum operating hours of the bus lane	0: 12:00-21:00, 1: 9:00-21:00, 2: 6:00-21:00, 3: other	0: 38.1, 1: 23.4, 2: 10, 3: 28.5

Other operational characteristics of the bus lane were gathered through the questionnaire-survey mentioned above. The majority of the interviewees were regular users of the specific bus lines. Most were aged between 40-54 years old (27.3%) and there was an equal distribution between males and females who participated. Over half of the interviewees were residents of the impact area of the bus lane and the majority had been using the specific bus lines before its implementation. The perceived average waiting time at the bus stops was mainly in the range of 8-12 minutes and most passengers used the buses for a length of up to 10 bus stops; meaning that they were on-board for a long period both before and after their bus entered and exited the bus lane section.

Notably, as the passengers' walking times to and from the bus stop was on average less than 10 minutes, this figure was used to determine the impact area of the specific bus lane. Assuming a walking speed of around 5km/h, the impact area can be defined by a buffer zone of 834 m around the bus lane (maximum value). Interestingly, most of the passengers interviewed experienced a total travel time gain following the

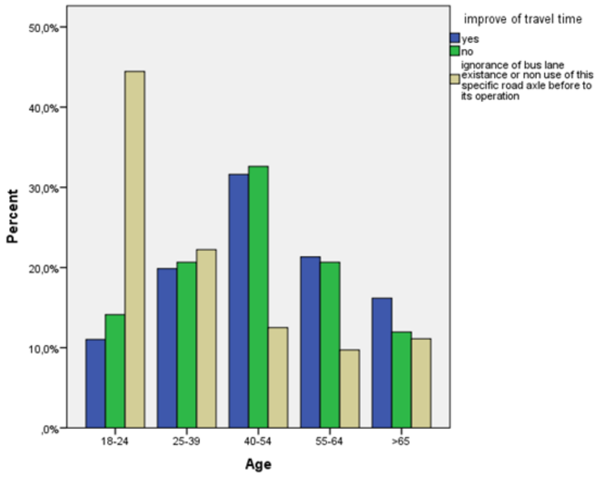

Fig. 4: Correlation between "age" and "travel time improvement after the implementation of the bus lane

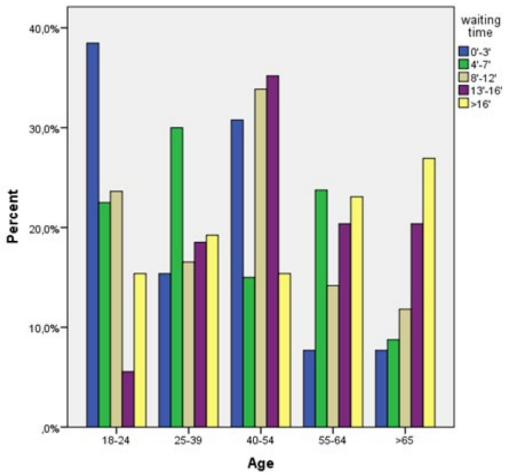

Fig. 5: Correlation between "age" and "passengers waiting time at a bus stop

implementation of the bus lane, with most of them stating time savings of between 4 and 7 minutes. Finally, the operating hours were considered satisfactory by most of the interviewees.

The collective results of the descriptive statistics for the bus lane studied are presented in Table 1.
Inferential statistical analysis was performed using the IBM Statistical Package for the Social Sciences (SPSS) Statistics 23. The first correlation refers to the variables "age" and the variable "time travel improvement after the implementation of the bus lane". The test was performed using Kruskal-Wallis H test ($p < 0.05$). A strong correlation between those two variables existed. As shown in Fig. 4, when the age of the interviewers increases up to the age of 54 years old, the positive answers for the existence of time travel improvement increases. The next correlation refers to the variables "age" and "passengers waiting time at the bus stop". The test used was the Spearman Rho test ($p > 0.05$). There is also a strong correlation between those two variables. As shown in Fig. 5, as age increases the perceived waiting time of the passengers waiting at the bus stop increases as well.

The key findings of this specific analysis include the following:

- Passengers' observed waiting time at the bus stop lies between 0-3 minutes. The respective perceived time is much higher.

- The average speed of buses is lower during bus lane operation hours than during the non-operation ones, something which was highly unexpected. This happens because of the bus lane violations made by the drivers of private cars.

- Parking demand exceeds parking supply in the impact area of the bus lane and therefore illegal parking along the bus lane seriously affects its efficiency.

- Perceived waiting time at the bus stop is increased along with the age of the interviewees.

- Perceived travel time in the bus (along the bus lane) is increased along with the age of the interviewees (up to the age of 54 years old).

4. Conclusions

This study provides support for decision-makers concerned with the design and operation of a short, low-cost outbound bus lane. A combination of field-counts and a questionnaire-based survey was used for the purposes of the evaluation.

Although the implementation of the bus lane cannot be fully justified in terms of the number of buses served per hour, it can still help passengers feel good about the travel time savings that it does provide. In general, this outbound bus lane can improve the travel time of the bus lines under certain conditions; parking enforcement is necessary to prevent violations by drivers of private cars that impact the bus lane's efficacy. That is, in terms of the bus's operation, the main objective must be to maximise uninterrupted bus flow. In terms of the passengers, perceived time gains are related to their age and the total time they spend on the bus.

The literature regarding bus lanes suggests that they should be of extensive length to justify their creation. The results of this study show, however, that short bus lanes can be beneficial as their implementation offers increased satisfaction to the users, over and above the time savings they provide.

Policy recommendations derived from this research can be summarized as follows:

a. Enforcement is very important since drivers are used to violating the outbound direction bus lane when they realize that bus frequency is not high.

b. Given that the pressure for parking spaces is high in residential areas where outbound bus lanes are mainly implemented, an effective parking policy should be in place before the implementation of the outbound direction bus lane.

c. Passengers must be informed well in advance of the potential benefits of the outbound direction bus (e.g., time reliability) to better appreciate and realize them.

d. Ongoing and constant evaluation of the benefits of the bus lane (especially less-common forms and schemes such as this one) is needed to enable local authorities and operators to make informed decisions about continuing or adjusting the operation of the bus lane.

e. Operating hours must allow for local conditions and the habits of the residents, employees, and visitors of the bus lane impact area so to minimize any negative effects.

One limitation of the research has to do with the fact that the perceived waiting time at bus stops cannot be directly compared to the actual waiting time since the interviewees are not the same passengers as the ones for whom the actual waiting time was observed. In addition, data concerning the performance of the bus system in the study area before the implementation of the bus lane is not available. Therefore, a "before" and "after" evaluation cannot be made. Finally, the use of video recording will be adopted in the next steps of this research to increase the reliability of bus passenger waiting time counts at bus stops

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Keywords

Bus lanes, urban traffic, Thessaloniki, Public transport, feasibility of bus lanes, Priority for public transport.

Developing the Social Dimension of Sustainable Urban Mobility: The ECCENTRIC Project in Madrid

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Abstract

This paper explores the difficulties of properly developing the social dimension of the sustainable mobility paradigm in urban mobility. It analyses the experience and results of one of the threes implementing actions funded by the CIVITAS initiative in the 2016-2020 period: the ECCENTRIC project implemented in 5 cities, including Madrid. As in the other participating cities, in Madrid most of the planned measures were successfully implemented and achieved their self-defined sustainability targets. However. the project struggled to address the social challenges in its living labs. This experience suggests that innovation in urban mobility may be responding more to the expectations of European "mobile elites" than to bridging the growing social gap in cities. It also sends a strong message to benefit more from the social potential of sustainable mobility measures, by embedding them within wider social and urban regeneration strategies. Finally, it calls for a social turn in the EU urban mobility initiatives to better address the social dimension of sustainability in future.

1. Introduction

The social dimension of the sustainable mobility paradigm has received comparatively less attention than its environmental and economic counterparts. This paper explores the reasons for such a biased understanding of sustainable mobility, taking as an example the experience and results of ECCENTRIC, a Horizon2020-funded project within the CIVITAS initiative started in September 2016 and running for four years in Madrid, Munich, Ruse, Stockholm, and Turku. The project intended to deploy 50 sustainable urban mobility measures in these cities, 11 of them in Madrid, with a focus on high-density urban neighbourhoods located outside, but close to the city centre.

The early and sustained contribution of the EU research and innovation policy in the consolidation of the sustainable urban mobility (SUM) concept (EC, 1992; EC, 2001; EC, 2013) has probably been one reason explaining the strong role played by new technological solutions in many sustainable urban mobility (SUM) flagship projects, including those within the CIVITAS Initiative. It can also explain the strong role played by utilitarian concepts- from time savings to marginal emission mitigation costs- in the design and assessment of plans and measures (Ricci, 2006) and the focus on the mobility challenges in city centres and suburbia. Generally, the deployment of SUM in European cities has been widely recognized as an EU success story by many stakeholders (Rupprecht Consult, 2019).

The difficulties in accommodating the social dimension of sustainability with mainstream SUM practice is evident when a project targets socially-excluded high-density neighbourhoods but it is not exclusive of them. Grieco (2015) states the lack of an adequate definition of social sustainability in urban transport; she highlights the oversimplification made in the consideration of the social dimension of sustainability in urban mobility as an issue of affordability and availability. Grieco continues, arguing that there is a need for a methodological change in transport planning regarding social issues, which should be supported by an effort to gather adequate and more detailed data.

The social dimension of SUM should not be reduced to the functional characteristics of the transport system. As in the case of any other public policy, there is a need to consider the mobility regimes and control systems that create a measurable situation of uneven mobilities (Sheller, 2018, p.18) among individuals. Building upon the thesis of Sheller (and also Sheller & Urry, 2006, p.213) that "time spent travelling is not dead time that people always seek to minimise", Miciukiewicz (2013) adds one additional level of complexity to the social dimension of SUM, the quality of the time spent travelling, its capacity to facilitate or jeopardise social interaction, and to contribute to self-realisation.

2. The ECCENTRIC project in Madrid (2016-2020)

ECCENTRIC (an acronym standing for 'innovative solutions for sustainable mobility of people in suburban city districts and emission free freight logistics in urban centres') is one of the three demonstration projects funded by CIVITAS within the EU research programme Horizon 2020, running between September 2016 and October 2020. It involves the cities of Madrid, Munich, Ruse, Stockholm, and Turku. These cities have in common a growing interest in implementing high quality and viable SUM measures in neighbourhoods outside the city centre. The challenge is to implement innovative SUM solutions in peripheral districts called living-labs (Aparicio, 2020). The living lab in Madrid is Vallecas, a district at the south-east of the municipality, with 328,000 inhabitants. Following the description of social sustainability proposed by Sheller (2018), two main challenges can be identified in Vallecas, regarding the differences in mobility associated to both, social class differences (significantly lower income levels and educational attainment levels compared to the city average), and differences in the quality of the built environment (public and private).

The project team approached Vallecas looking for "insight into the social practices and material agencies of contemporary mobile lives" (Sheller, 2018, p.20). They were particularly interested in understanding how motility (i.e, the capital or potential of mobility, as defined by Kaufmann, 2004) is severely restrained for some social groups (children and the elderly) or for some residents (those relying on walking and cycling), compared to other citizens and particularly to the mobile elite usually favoured by mainstream SUM policies targeting the central districts and more affluent suburbs. Following the categories suggested by Sheller (2018, p.24), the team focused on two scales: the body scale (the physical differences, in this case those due to age, influencing the ability of children and the elderly to move) and the street scale (the shaping of built environments in Vallecas hostile to some sustainable mobility practices). Initially, the project was not paying much attention to the quality of the transport experience or, in Miciukiewicz's (2013) words, to transport as an end-in-itself. However, this dimension of social sustainability soon became relevant, during the interaction with senior citizens in the context of measure 2.8, for example.

The project in Madrid included 11 measures of very different nature, as presented in Table 1. The code in the table is used throughout the paper to refer to each measure.

Table 1: Code of various measures used in the study

CODE	Measure Name	Measure Description
2.3	Adaptive parking management based on energy efficiency and occupancy	A smart parking management scheme was tested in the municipal bus (EMT) headquarters, located in the demonstration area. The system surveyed vehicle occupancy, so that parking priority was given to HOVs and low-emission vehicles in the context of the EMT's Company Mobility Plan-
2.8	Mobility management strategies for vulnerable groups with a gender approach	A focus on vulnerable groups (children and elderly), identifying actions through a collaborative process and building upon inputs from recent psychology research. For children's mobility, the methodology builds upon the successful results of the previous project STARS. The actions focused on the elderly were based on the projects implemented in Madrid regarding health and active life.
3.3	Open platform for multimodal mobility information and services	An open mobility data portal with multimodal information from different sources (public and private transport, traffic, public bicycles, air quality, etc.) was created as a basis for the development of new mobility information services and products by interested companies, institutions, and individuals.
4.1	Innovative and participative approach to traffic safety at neighborhood level	A comprehensive road safety study, supported by the analysis of key urban parameters, served as a basis for the development of a GIS-based application collecting road safety incidents. Residents' safety perception is also analyzed through a systematic review of social media and other sources of information.
4.6	Pedestrian friendly public space outside the city Centre	Improving walking conditions in one area in Vallecas. Inter alia, a high-quality pedestrian itinerary (Paseo Miradores) is created, improving the quality of the public space.
4.7	Enabling cycling outside the city Centre	Prioritizing the shared use of road space in the demonstration area. Bike use was fostered through the implementation of bike lanes and other initiatives.
5.1	High-level public transport service corridors in peripheral districts	The objective is to improve the quality of the bus service and increase the bus patronage on a tangential corridor linking the eastern periphery. The study assessed different solutions; completing the design of a 3-km pilot section, but it was dismissed by the municipality.
5.8	Electric and hybrid buses for public transport	Service needs were analyzed to select the best hybrid bus solution. The new buses were assigned to server a tangential bus line in the eastern periphery, partially overlapping the PT corridor analysed in measure 5.1. Buses' performance served to design future renewal plans of the city's bus fleet.
6.2	Test fleets, policy incentives and campaigns for the uptake of electric vehicles	The municipality fostered the use of electric vehicles within its own services as well as by local private companies and expanded the electric charging network in the city. Based on the monitored vehicle performance of in the pilot, new strategies were designed to promote the uptake of electric vehicles.
7.1	Consolidation Centre with EVs and local regulations for clean urban freight logistics	Based on a detailed analysis of the urban logistics sector in Madrid, a pilot urban consolidation Centre for last mile distribution was implemented. The pilot included the use of low-emission delivery vehicles.
7.6	Prototype for an ultra-low emission cargo vehicle	Development and demonstration of a 5.5-ton electric truck prototype, adapted to the specific needs of Madrid's urban delivery sector. It was expected to be tested under real conditions, but the COVID-19 pandemic delayed the completion of this measure.

The project combined three measures (2.3, 4.1, 5.8) that were implemented in the living lab, but not tailored specifically to it, four measures (3.3, 6.2, 7.1 and 7.6) of a city-wide nature, and four measures (2.8, 4.6, 4.7 and 5.1) specifically designed for Vallecas. These three clusters of measures mirror the three structures of governance defined within New Institutional Economics (NIE) and applied by Mercier (2009) to the analysis of equity in urban mobility policies: market, contract, and hierarchy. In NIE, these categories apply to the adequate degree of externalisation of activities by one enterprise: activities under the market category are easily externalised and do not require any permanent contracts; activities under the second category require some kind of long-term commitment with the provider; activities under the third category are better carried out within the enterprise itself. In accordance with Mercier, experience shows that social issues need hierarchical governance, as they are complex problems linked with many other sectors; or in his words "a bundle of tangled elements sensitive to design", where action from transport policy is not necessarily more efficient than action from other sectoral policies. This is the case of the third ECCENTRIC cluster in Madrid. The second cluster needs medium to long-term commitments between the local government and the private sector to achieve the desired results. As for the first cluster, the local government typically expects that the external contractor will provide the requested products in the short term, ready to be operated. As the NIE denominations are not too illustrative when applied to this case in particular, the clusters are renamed as "policy" (instead of hierarchy), "partnership" (instead of contract) and "means" (instead of market).

During the project, it became obvious that market or means measures are the professionals' favourites. They deliver instrumental advantages, provided that institutions are sufficiently prepared and staffed to manage the new tools. They are neutral from a context and a policy perspective, although there are some claims regarding their ability to provide better information that empowers the authorities to better justify and implement future SUM initiatives.

Contract or partnership measures are technologically disruptive. They do not make sense economically in the short term and need significant public resources. There is little or no interest in tailoring them to local conditions as they have the ambition of being implemented in multiple cities and contexts; they are the preferred approach of mainstream SUM approaches. While most of them never reach full deployment, and the initial pilots usually disappear after a few months or years of operation, a few of them manage to be consolidated and widely replicated, becoming competitive in open markets.

As for hierarchical or policy measures, they have the potential to make a significant local impact, including from a social sustainability perspective, but need strong involvement of decision-makers, and are carefully tailored to fit local conditions. Under the conventional understanding and practice of SUM, these measures face significant challenges and hurdles, as was illustrated in the measures implemented by ECCENTRIC in Vallecas: For example, in the case of working with children to change their mobility behaviour (measure 2.8), despite the high acceptance of SUM concepts among school pupils, the social framework conditions were hostile to modal change. That is, many families (and low-income ones in particular) make their mobility decisions in an unfriendly urban environment under overstressed conditions. In the case of seniors attending Elderly Community Centres, their actual priorities were related to the quality of the travel experience, including respectful social interaction in public transport and availability of friendly public spaces for pedestrians.

Measure 4.6 focused on improving walking conditions in key sections of the street network. Contrary to the usual practice, the project team in this case was careful not to impose aggressive on-street parking restrictions on residents, particularly at night. This was consistent with the social conditions in the area where many residents were unable to afford the cost of off-street parking, and the built environment featured many narrow streets well suited to coexistence solutions in which the car loses its traditional priority, even when parking is authorised.

As for measure 4.7 (supporting bike use in the living lab), the project team's approach was to integrate the more densely populated parts of the living lab within the municipal effort to expand cycling infrastructure; regrettably, this effort did not result in any improvement in the general level of satisfaction of bikers in the area, suggesting the need for actions much bolder than those that could be implemented in the context of this project.

Finally, the high-quality bus corridor envisaged in measure 5.1 was not implemented. Although the estimated budget was just € 4-to-5 million, the municipality decided that it was not an investment deserving priority, on the grounds that the benefits for residents were unclear and that there were other investment priorities in the area outside the transport sector. Whereas the measure would have provided operational improvements benefiting bus users, decision-makers felt that residents at large were hardly getting any benefits.

3. Lessons learnt

The ECCENTRIC team in Madrid was somehow frustrated by the unexpected difficulties in developing the social dimension of sustainable mobility in an innovation project. The team realized that there are some traits in transport innovation which can, in fact, have a regressive social character, inter alia because most of the sustainable mobility measures promoted in CIVITAS and other innovation initiatives involve the use of expensive technology. Early adopters (able to overpay for the services provided by these technologies until they are mature enough to become cheaper and more accessible to others) are essential for innovations to survive, and public institutions are often requested to play this necessary but expensive role. Public subsidies and incentives compete with social programs for the limited resources available in public budgets. Furthermore, since innovative services tend to target and be used primarily by a mobile elite characterized by higher education, income, and quality of life, public financial support offered to them often results in regressive income transfers.

To cope with the requirements of social sustainability, mobility measures need to be consistent with and ideally, embedded within broader social policies that address residents and their urban environment. In cities where basic mobility needs are reasonably covered, residents may have difficulties in understanding the need for additional transport investments, usually based on environmental targets, when these resources could be dedicated to many pressing social priorities in their neighbourhood. This position is consistent with the results achieved in Vallecas by measure 4.6 (pedestrians) compared with measure 4.7 (cycling) and, especially, with measure 5.1 (high-quality bus corridor). Furthermore, and contrary to aggressive car-reduction measures in central districts, the evidence showed that a more cautious and better tailored approach is necessary in socially stressed neighbourhoods where car use is critical for many low-income residents relying on short-term contracts and who look for low-paid jobs popping up in different places around the metropolitan region, particularly at a time when the population is increasingly reliant on such jobs: From a social sustainability perspective, it appears more relevant to dedicate resources to the regulation of the job market than to the use of cars by these workers. Accordingly, the improvement of pedestrian and cycling infrastructure in Vallecas followed a coexistence approach among modes, privileging residents by avoiding any reduction to on-street parking, whilst reducing car speeds and the space dedicated to traffic.

The project team realized that the social dimension of sustainability was not properly covered by the existing CIVITAS framework for project evaluation (as described, for example, in Dziekan et al, 2013), which privileges the use of quantitative key performance indicators usually linked to functional performance and environmental objectives. In this approach, the social dimension is mainly considered within the qualitative assessment of participation during the measure implementation process. This weakness is consistent with the general lack of data, information, and methodological tools in what refers to social sustainability in transport (Grieco, 2015) and cannot be solved at the project level. Rather, it calls for a specific research and innovation effort to produce the adequate tools for mobility researchers and policy makers.

One controversial and frequently discussed issue within the research team was the large size of the living lab in Madrid. The main advantages of this choice were the possibility to look for alternative locations within the living lab, should any unexpected difficulties make it impossible to implement some actions in the originally envisaged location. On the downside, participation and monitoring became more challenging, both requiring virtually tailor-made approaches for each measure, which revealed limitations in terms of the representativeness of the information collected for stakeholders, users, and residents. Therefore, it can be stated that reducing the size of the living lab allows for more meaningful participatory and assessment processes at a lower cost, but that this requires extensive preparatory and exploratory work to guarantee the feasibility and actual implementation of the planned measures.

4. Conclusion

The ECCENTRIC experience in Madrid generally confirmed that the European SUM concept is not adequately addressing the social dimension of sustainability, and that this bias results in the dominance of a socially-blind approach, in which policies and their associated resources (particularly in research and innovation) are disproportionately dedicated to the most central locations in cities and the development of measures targeting a mobile elite who are eager to test new mobility solutions and to increase their “motility” or mobility potential.

This bias can be addressed by dedicating more attention to the adaptation and implementation of SUM in socially stressed neighbourhoods. Significantly, this requires painful changes in the approach, moving from the current autonomy of urban policy (particularly with regards to innovation) towards its integration within social and urban regeneration strategies and plans. Otherwise, the mere transfer of SUM measures from city centres and suburbia to these neighbourhoods is likely to result in additional burdens placed upon the already troubled daily lives of residents. Moreover, it will likely lead to the waste of unnecessary public resources in transport that could be better used in other public policies targeting these neighbourhoods. To actually contribute to better living conditions, SUM measures and policies need to be implemented in an urban framework in which minimum social conditions are met; an approach that can be achieved by embedding these measures within social policies. In the current European context of growing inequalities and increasingly flexible and uncertain (that is, casualized and precarious) employment, these framework conditions are less and less likely to be taken for granted.

SUM policies need to go beyond the oversimplification of the urban context (in both physical and social terms), made in many of the existing sustainable urban mobility plans (SUMP), where social complexity and tensions are erased, and a utilitarian discourse to improve the mobility of all citizens prevails. Moreover, since SUMP involves micro-planning, in which poorly coordinated services produce a multiplicity of largely overlapping plans (on mobility, air quality, energy efficiency, climate change…), it fails to address the social dimension of sustainability. Hence, even though SUMPs have provided a dramatic step forward compared to previous traffic planning practice, it is high time to keep moving forward. Specifically, the social dimension of sustainable mobility can better be served the other way round: making transport more explicit within urban regeneration and social inclusion policies that aim at reaching better and more equitable living conditions. Simply put: SUM principles are better implemented by embedding them in social and urban regeneration actions to gain real support from vulnerable social groups and developing measures and actions based on that support.

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Keywords

Urban mobility. Innovation. Public policy. Transport governance.

Enhancing Mobility as a Service (MaaS) Concept through Social Interaction and Crowdsourcing Applications

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Abstract

Mobility as a Service concept comes to support optimization on addressing mobility needs through the proper handling and use of information. Aiming at a seamless mobility approach that is aligned with urban sustainability goals, social interaction and crowdsourcing applications may further support the MaaS concept, by making use of big data and by connecting common interest user clusters under a dynamic information exchange environment to assist travellers with their mobility and parking decisions. This paper discusses finding from two research projects that support this vision proposing sustainable solutions for urban mobility and parking by promoting shared mobility and parking options in Mediterranean urban areas.

1. Introduction

The rapid growth of private transport usage, especially in metropolitan areas, is linked with increased traffic congestion and pollution (Nguyen-Phuoc et al., 2018). Most urban environments, follow the heavily car-dependent urban model, that is also linked with imbalance between parking supply and demand which can be considered the initial reason for metropolis parking problems (Hossam El-Din, 2017). Adding to that, cruising for curbside parking further increases the overall traffic congestion (Dowling et al., 2017). It is common ground that one way of depreciating public space in the urban environment is to occupy it by parked vehicles, and particularly by abusive / illegal parking, as well as by traveling a long way in search of free parking spaces.

Considering the dense environment of most Mediterranean cities, and especially ones with historic and commercial centres, having limited public space to serve all urban functions, the need to seek for sustainable solutions in order to avoid their degradation is fundamental. Urban transportation is linked with city liveability (Gössling, 2020) and thus, transport related actions are required.

Mobility as a Service (MaaS) can be an efficient tool for managing travel demand and supporting modal shifts in favour of "greener" transport modes (ie. walking, cycling, micro-mobility and sharing mobility options) (Durand et al., 2018).

Towards this view and considering that the main urban mobility problems deal with the increased traffic and the lack of parking spaces, approaches that support and go beyond the MaaS concept may significantly contribute to urban sustainability.

This research comes to support the MaaS concept, while taking advantage of social interaction and crowdsourcing information, by promoting a sustainable urban mobility approach, combining; a) sharing mobility and b) sharing parking concepts, appropriate for Mediterranean cities, introducing at the same time a new "culture of living and moving" in urban areas.

Based on findings from two research projects; SocialCar and SocialPark (one European and one National) with a list of Mediterranean cities involved, this research provides insights that social input and proper use of crowdsourcing information may significantly support MaaS and enhance mobility and parking sharing concepts and urban liveability.

Promoting sharing mobility and parking options in Mediterranean urban areas through social interaction and crowdsourcing

Shared mobility options have been widely introduced in most urban environments to overcome the need of vehicle ownership and/or usage, providing at the same time convenient mobility services to travellers based on their needs (Shaheen et al., 2016), through a new mobility concept, covering a list of modes; like car, bike, moto and scooter (Shaheen and Cohen, 2019).

Additionally, promoting MaaS seems vital for urban sustainability. The MaaS concept usually supports a platform development,that integrates all modes and services to cover mobility needs of travellers in the best possible way (Mulley, 2017; Arias-Molinares and García-Palomares, 2020).

Reducing road congestion can be achieved by improving and maximizing connectivity and information sharing between carpooling and other transport services. SocialCar project followed this approach, by providing real-time information exchange and validating targeted and customized mobility solutions regarding behavioural changes of travellers in favour of car-pooling and eco-friendly travel choices. Adding to that approach, SocialPARK project supports overcoming further needs for parking arrangements, as it deals with the limited parking spaces problem in urban environments, through the activation of an ecosystem of interacting citizens, parking companies and municipalities, towards a mutually profitable management of the publicly available parking space.

Social interaction has been critical for both projects, supporting the participatory approach on urban mobility. Both approaches, make use of crowdsourcing information and data, supporting community activities (i.e. communication to exchange and verify traffic information, service rating, parking availability notice along with and additional information that may be exchanged and support improving travel/parking experience).

2. Methodology

Sharing mobility options have been tested through a smart mobile application, developed within SocialCar project as " a new communication network for intelligent mobility, sharing information of car-pooling, integrated with existing transport and mobility systems". Aiming at simplifying travel experience of citizens and having defined data processing flows and designed algorithms to match travel requests with the integrated public-private transport supply, complemented by a reputation-based mechanism, the application has been tested in 10 European sites (Edinburgh, Brussels, Canton Ticino, Zagreb, Torino, Brescia, Lazio Region, Luxembourg, Ljubljana, and Skopje) (Wright et al., 2017; Kalogirou et al., 2018), through three discrete test phases. Test A, aimed at identifying all application related bugs in order to meet user preferences, decrease complexity of use, improve clarity of information, memorize preferences and improve suggestions, improve usefulness and user friendliness and making the application more intuitive. Test B evaluated how effective the developed application could be in the future and Test C assessed how likely it was for travellers to change their mobility behaviour while using the application (Wright et al., 2017; 2018; Kalogirou et al., 2018). Focusing on Test C, a number of travellers from four test sites (Brussels, Ticino, Ljubljana and Edinburgh) used the application for a trial period, in order to cover their actual mobility needs. Users' selections provided useful knowledge for the behaviour of travellers, their preferences and possible mode shifts in favour of carpooling and combined carpooling and Public Transportation (PT) options.

Similarly, the sharing parking concept is being examined, as part of the SocialPARK's project "integrated Parking-as-a-Service platform for facilitating search of vacant parking lots based on crowd-sourced Information". Having as test site the city of Thessaloniki, in Greece, a typical Mediterranean city, all possible parking options have been captured along with the relevant users' and stakeholders' needs, wants and preferences. That feedback supported the development of the relevant Use Cases and project platform, to be further tested, capturing actual users' parking related requirements, social interaction and behaviour. Although it is an ongoing project and test phases have not yet been implemented to assess project impact, several preliminary findings are being available, proving the need for such solutions (Tsami et al., 2019).

3. Results

Counting on average around 1500 carpool trip offers from external carpool providers, and 15000 trip planning solutions being provided to users during the testing period of the SocialCar project, the total number of trip suggestions that included a carpooling offer were 2781 (approx. 19% of all solutions presented to users), while 15% of trip planning solutions, resulted in users pursuing carpooling (either by making an enquiry for a specific carpool trip to the external carpool provider or by booking an internal carpool trip via the application). A critical finding was that the majority of carpooling trip solutions offered to travellers were connected with PT (over 85% for Brussels, Ticino and Ljubljana and 69% for Edinburgh) (Wright et al., 2017; 2018).

The trial testing period of SocialCar application, indicated that mobility conditions and travellers' behaviour may shift to more sustainable solutions, decreasing the car usage and increasing sharing and public transportation mobility options. Additionally, results of testing showed that the application is likely to benefit more, corridors and daily time slots with the highest congestion. Still, car parking capacity at the most attractive connection points was the major constraint on achieving the potential impacts (Wright et al., 2018).

Findings from capturing parking conditions, needs and preferences of citizens in the urban area of Thessaloniki showed that 75% of urban travellers face difficulties in finding a parking space at the city centre, while 89% of them park their cars on street and only 11% in parking lots. Still, 83% of them indicated their willingness to use a parking space after improving current cost policy. Based on this research, 92% of citizens revealed their interest and willingness to use the SocialPARK application (Tsakiropoulou et al., 2018).

4. Concluding Discussion

Considering both sharing mobility and parking concepts, following both projects' findings, urban mobility could be significantly supported by advanced and enhanced MaaS concepts, taking advantage of social activation and interaction capabilities and crowdsourcing data and applications. Carpooling in a frame of being combined with convenient PT, parking availability sharing information and incentives for behavioural changes in favour of such solutions, may support the urban sustainability goal of the Mediterranean urban environments and beyond.

In that frame, policy measures supporting carpooling to make it more attractive to car drivers, such as priority parking at PT interchanges or at workplaces, are strongly recommended. Additionally, both approaches discussed, require proper legislative changes for sharing mobility and parking operations.

Among the advantages of the sharing mobility concept discussed, is that it does not require all car users to change their mobility profile, shifting them massively to other means of transportation, instead, it offers to the devoted car users the possibility to co-travel and reduce travel expenses, given them the possibility to offer rides to others and contribute to the overall congestion reduction. On the other hand, sharing parking arrangements, could support the sharing mobility concept, offering parking slots for those who carpool and continue with PT under better pricing policies.

Exploiting the "wisdom of the crowd" for providing mobility and parking solutions in real time conditions, under a monitored and accurate frame of operation, adds on the creation of a novel value-chain for mobility and parking towards sustainability.

Future steps of this research could be to integrate in one application both sharing mobility concepts, being part of MaaS green packages, to be further tested in Mediterranean urban areas, allowing comparisons among the different cities and covering city-oriented needs and preferences.

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Keywords

Mobility as a Service; shared mobility; shared parking; carpooling; crowdsourcing applications.

Data and Perspectives on E-Scooters use in Mediterranean Cities

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Abstract

The issue of micromobility has been raised suddenly in recent years and although it includes several transportation modes, in shared or private form, shared e-scooters have become the fastest growing trend. While private e-scooters have been on the market for decades, the phenomenon of the shared e-scooter systems emerged mainly due to the advances of innovative technologies. However, the main question today is how e-scooters could be integrated into the urban environment of cities in terms of environmental, economic, and social performance, especially towards providing better first/last/only-mile connectivity. The answer is not simple because their sustainability in relation to the mobility system is mainly determined by how they are used and what they replace. If an e-scooter trip replaces a motorcycle or a car trip, the environmental and health effects are positive. If it replaces a trip on foot or by bike, the situation gets worse. This paper gives an overview of e-scooters' use in Mediterranean cities, presents some preliminary results of a relevant ongoing quantitative survey in Greece, and offers a discussion on available data, challenges, and perspectives. The rides of shared e-scooters in several Mediterranean cities have overcome the one (1) million in just 10-12 months after their availability, while private e-scooter market shows also a growing demand. Given that this new mode of transport is still in its infancy, in this paper we examine the first indications in regard to its necessity, attractiveness, safety, cost, people's attitudes, and integration into the urban environment focusing on Mediterranean cities.

1. Introduction

Air and noise pollution, traffic congestion, and long commuting times are some of the transport-related issues in cities that deteriorate the quality of life (United Nations Human Settlements Programme [UN-Habitat], 2016; European Commission, 2019a). A decrease in ownership of private vehicles in favour of efficient and connected public transport modes, improved walking and bicycling infrastructure, congestion charges and shared mobility could substantially ease these problems and facilitate cities towards establishing sustainable mobility conditions (United Nations, 2017; European Commission, 2019b, 2019c). The changing of urban policies towards sustainability in Mediterranean cities is a process that has started long ago (Antoine, 2002), gradually evolving them into a sustaining and sustainable habitat (Vanderburg, 2004). In this frame, the role of public transport and tethered vehicles (Dahlström, 2002; Gilbert, 2004) and the promotion of innovation in this field (Tsafarakis et al., 2019; Nalmpantis, Roukouni, Genitsaris, Stamelou, & Naniopoulos 2019) is crucial, while active and non-motorized mobility is expected to have an even more important role to play in cities in the future (Havlick, 2004).

Towards these goals, the issue of micromobility, as defined by Brunner, Hirz, Hirschberg, and Fallast (2018), or "shared micro-mobility" (Shaheen & Cohen, 2019), has been raised suddenly in recent years in the urban transport sector, allowing e.g. pedal bikes, e-bikes, and e-scooters to enter in the cities on a "large" scale. Although micromobility includes several different service models and travel modes, in a shared or personal form (e.g., bicycles, skateboards, kick scooters, segways, hoverboards, etc.), shared electric scooters have become the fastest growing micromobility mode since their introduction, three years ago (Institute for Transportation and Development Policy [ITDP], 2019). While personal e-scooters have been on the market for decades, the phenomenon of shared e-scooter systems emerged mainly due to the advances of innovative technologies (e.g., improved battery technology, smartphones, Global Positioning System [GPS], mobile payment systems, etc.). According to Giannopoulos and Munro (2019), "technological revolutions can produce permanent structural changes in how societies and economies function, operate, and collaborate domestically and internationally and envision the future". The question and research today focus on how these electric kick scooters could be integrated into the urban environment of cities in terms of environmental, economic, and social performance.

In the context of this paper, recent data on e-scooters use in European Mediterranean cities are presented and discussed, also highlighting the relevant challenges and perspectives. In the second chapter, the methods used are presented. Next, in the third chapter, there are results and discussion. In the fourth and final chapter, conclusions are drawn and directions for further research are proposed.

2. Methodology

The data and the results in this paper derive mainly from the international literature (e.g., journals, books, conference and seminar proceedings, scientific and business reports, regulatory and legislative framework) including web resources, such as online texts, news and announcements published in newspapers, television and radio shows, and shared e-scooters providers' websites.

Moreover, some preliminary data from an ongoing quantitative survey of dockless and personal e-scooter users in the city of Thessaloniki, Greece, conducted in the frame of an undergraduate thesis in the School of Civil Engineering of the Aristotle University of Thessaloniki (AUTh), are indicatively presented. The survey is conducted with the use of an online questionnaire and a series of personal interviews with e-scooter users aiming to identify their profile, outline the uses of e-scooters, and understand and register the challenges and impacts of this transport mode on urban mobility practices. Before the dissemination of the survey, some exploratory interviews have been conducted with current users for providing a first point of view on how the survey's issues were perceived by them and forming the construction of the questionnaire. The online questionnaire is disseminated and promoted via social networks (e.g. Facebook) and e-mailing to specific e-mail addresses, while interviews with users are being conducted on docking points around the city, at different times of the day (morning, midday, and afternoon) and during all the days of the week, when the users intend to rent an e-scooter. The personal interviews were selected for allowing the verification and elaboration on various assumptions formulated after the analysis of the responses. In this frame, the questions comprise various topics such as who are the e-scooters users, the frequency of use, the obstacles and motivation on their use, where the users ride, how users react on several regulatory perspectives if trips are taken collectively or individually, the degree of modal shift, and trips that favour intermodal practices.

So far, 135 user responses have been collected and 29 semi-structured interviews with e-scooter users have been conducted. The aim is to gather about 400 responses from different users, so as to obtain a representative sample and keep the confidence level at 95% and the confidence interval equal to 5 (given that the city's population is about 1.000.000 people). To the best of our knowledge, no published questionnaire survey on the issue has been conducted in Greece so far.

All information mentioned in this paper regarding the stand-up e-scooter and not the e-scooter on which the driver sits, both in docked and dockless schemes.

3. Results and Discussion

The inhabitants of Thessaloniki, Greece, were the first residents of a Mediterranean city to have the opportunity to travel around the city on rented dockless e-scooters of Neutron Holdings Inc., known as Lime, since 2018 (Kokkinidis, 2018), while during the same year similar rental services began to be implemented in other Mediterranean countries such as France, Spain, and Portugal. Cyprus, Italy, Malta, and Slovenia followed in 2019, however, such a sharing system has not been recorded so far in other European Mediterranean countries (e.g., Croatia, Albania, Monaco, Montenegro, and Bosnia and Herzegovina). Following e-scooter sharing systems furious spring and growing popularity worldwide, some recent posts report that sharing providers are retreating from certain cities' markets and laying off staff, looking for profitability, survival, and consolidation (e.g., Buckley, 2019; Bliss, 2020; McFarland, 2020). For example, in Greece, Hive, one of the largest e-scooter companies, announced in February 2020, a year after its arrival in the Greek market, that it decided not to continue its services due to "the absence of an integrated legal framework that creates an organized business environment" (Skiannis, 2020a). The reasoning of Hive's decision expresses the present situation in many countries around the world where e-scooter providers, planners, residents, and decision-makers are not yet ready enough to manage efficiently the challenges and considerations of the boom of this type of micromobility. Similarly, in Spain, Betancourt (2020) indicates that e-scooter companies failed in their first year (2019) in Spain, mentioning also that 11 providers have left the country or stopped operating.

Do Mediterranean cities need e-scooters?

According to the "Mobility for nearly zero CO2 in Mediterranean tourism destinations" (MOBILITAS) project, rapid urbanization and heavy reliance on the use of conventionally fuelled private cars, make many Mediterranean cities today to face, among other challenges, congestion, noise and air pollution, and inadequacy of public transport (MOBILITAS, 2019). Furthermore, their exposure to the impacts of touristic seasonality adds up pressure on the need to plan for accessible, sustainable, and effective mobility transport modes. In Europe, approximately 50-60% of car traffic volume is caused by cars on trips less than eight km and vehicle traffic speeds in many city centers are averaging as little as 15 km per hour (Heineke, Kloss, Scurtu & Weig, 2019). According to the European Commission (2017), the average driver in Greece spent more than 36 hours in traffic congestion in 2017, in Italy more than 37 hours, in Cyprus more than 35 hours, and in France more than 30 hours.

In fact, as short-distance car trips account for a large share of motorized travel and public transport networks cannot make door-to-door trips, micromobility, in general, can be a key piece of an efficient transport system. This possibility has been also identified by the European Environment Agency (2019), which included e-scooters in the modes that can give solutions in the first and last mile of each trip, mainly by replacing a car or taxi trip. Available data for France (Paris, Lyon, and Marseille) show this proportion to be 8-10% (6t, 2019a, 2019b), while for Portugal (Lisbon) the figure increases up to 21% (Lime, 2018a). We may assume that in a city with very low car use, it is only natural that a very small fraction of e-scooter trips replace car trips. Although the large cities attract the attention of the various policies and media, Mediterranean small and medium-sized cities may face also similar challenges, e.g., in cases they have surrounding suburbs with big service gaps, intense tourism flows or they are very car-dependent. For example, in Greece, traffic congestion concerns not only the two largest cities of Athens and Thessaloniki but also the small and medium-sized ones (see Milakis, 2015; Giannoulis, 2019; Kordos, 2019). It should be also highlighted that the Mediterranean climate minimizes the sensitivity and limitations of e-scooters' use to weather conditions, unlike other European cities that generally have more rainy and cold days (Hardt & Bogenberger, 2019; Chang, Miranda-Moreno, Clewlow, & Sun, 2019).

If someone asks whether Mediterranean cities want e-scooters, the answer depends on about which city he/she asks. In general, e-scooters, electric bikes, and pedal bikes, either docked or dockless, if introduced properly, can be a transport alternative (e.g. for the first/last/only-mile option) to the car for distances of up to several km and alleviate some of the transport challenges that cities and their residents face. The main concerns with micromobility vehicles, and e-scooters in particular, are safety and whether cities' infrastructure and regulations can support the mass inflow of these modes of transportation. In any case, cities and e-scooter providers can work together to shape a way ahead that serves the public good, meets cities' goals, and enables providers of the private sector to establish viable business models. Collaboration among all stakeholders seems to be the way to go.

Do users favour e-scooters or other micromobility modes?

Although shared bicycle usage is still worldwide the most common way to get around (National Association of City Transportation Officials [NACTO], 2019), shared e-scooters in the USA overtook bicycles as the preferred vehicle for dockless vendors (Moore, 2019). This dynamic seems to be similar for several Mediterranean cities where shared e-scooters have been developed, taking into account the number of shared e-scooters rides announced only by Lime through its website: e.g. Greek and Spanish users have taken more than one million rides on Lime e-scooters after just 12 months (Lime, 2019a), Parisians took one million rides in just 120 days (Lime, 2018b), and Portuguese took more than 1.8 million rides in one year (Lime, 2019b). Specific data regarding the Greek e-scooter (shared and personal ones) market seems to confirm the aforementioned trend and demonstrate a strongly positive acceptance by customers and users. According to Skiannis (2019), there are currently around 4,000 e-scooters to be rented in Athens, Thessaloniki, and Crete, but the owned ones have surpassed this figure. Their sales began practically from zero in 2018 to reach around 4,000 by the end of that year, but positive user experiences have resulted in a "boom" of sales in 2019 when a total of 20,000 e-scooters are estimated to have been sold (Skiannis, 2019).

Considering e-scooters' popularity and market potential and since they address cities' sustainable mobility goals (e.g., reducing congestion, pollution, and private car use; complementing public transport; expanding access for underserved areas; etc.) this form of micromobility should be welcomed, despite the fact that it was introduced without consultation with local authorities and citizens. On the other hand, e-scooter users should show respect to other road users, and particularly to the vulnerable ones, by riding in regulated lanes, being sober, keeping speed limits and other traffic rules, parking in designated areas, wearing helmets, etc.

Is micro mobility safe?

The safety of both e-scooter users and other road users is another key concern in cities. Scientific publications and media accounts show cases of e-scooter riders being injured or injuring others, highlighting also an increasing rate of these kinds of accidents (Bekhit, Le Fevre, & Bergin, 2020; Namiri et al., 2020), but it is still unclear how dangerous they are compared to other transport modes and whether their use can create a gain for public health services by reducing car or motorcycle-based trips. Information from media reports of standing e-scooter fatalities show that at least 29 people have died in e-scooter crashes since 2018 worldwide (Griswold, 2020), while in Mediterranean countries, up until the end of 2019, there were six (6) e-scooter related deaths in France, five (5) in Spain (International Transport Forum [ITF], 2020), and one (1) in Greece (Politis, 2019), as well as a dozen of accidents with injuries for both users and pedestrians.

Considering that e-scooters have been on the streets for a limited time, relevant accidents will probably decline supposing that riders will become more familiar with e-scooters and stricter safety rules will be enforced both by the providers and national or local authorities (e.g. helmet requirement, speed limits, fines, dedicated corridors, etc.). In this frame, according to ITF (2020), the risk of a fatal traffic accident is as great on an e-scooter as on a bicycle, while motor vehicles are involved in about 80% of fatal accidents that occur with cyclists and e-scooter users. Thus, current data do not provide clear evidence of safety being a crucial concern for e-scooters use in Mediterranean cities.

However, besides the providers', cities', and national regulations, users have much more to do apart from just wearing a helmet. Users should ride carefully, without a passenger, not under the influence, and leave the scooter standing up and out of the way of pedestrians, people with disability, and road traffic, while initially they should have done a visual inspection, as well as perform a pre-ride check for damages and take a test-ride in case they are novice riders.

Is micro mobility economically advantageous?

Shared e-scooters in almost all European countries unlock for €1.0 and there is an additional charge of €0.15 for each minute of use. Thus, a ride of 10 minutes will cost €2.50. Assuming a mean velocity of 15 km/h, this cost corresponds to a route of 2.5 km length. Obviously, this is costlier in comparison to walking and private bicycling, and, at first sight, to public transportation.

Regarding the typical regular fare of riding a public bus in the Mediterranean cities, we can assume it to be approximately €1.50, with the note that there is usually a 50% discount valid for e.g., students and the elderly. Nevertheless, the fare varies among countries and cities: e.g., €1.0 in Thessaloniki, Greece, €1.3 in Zagreb, Croatia, €1.4 in Athens, Greece, €1.5 in Rome, Italy, €1.5 in Lisbon, Portugal, €1.5 in Valletta, Malta, €1.9 in Paris, France, and €2.0 in Madrid, Spain, according to information retrieved from the Organisation of Urban Transportation of Thessaloniki (2020) for Thessaloniki, Greece, and Globalprice (2020) for the rest of the cities. These prices are hard to beat, but there are some downsides to using public buses, such as the dozens of stops, the schedule keeping, the location of the pick-up and drop-off stops, the crowdedness, and the fact that there is no adequate public transport service after the midnight in some cities (e.g., in Thessaloniki, Greece).

Is e-scooter rental more expensive than driving a car? The mileage reimbursement for a car in Mediterranean countries varies from €0.15 to €0.57 per km (Eurodev, 2019). Accepting a mean value of €0.33 per km means that for 2.5 km the cost for the average person is about €0.83, i.e., €1.67 cheaper than riding an e-scooter. However, congestion, parking costs, and car payments are variables not included in this mileage rate, which could reduce the scale.

Regarding taxi cost, e-scooter use looks quite cheaper, using, indicatively, current data from Thessaloniki, Greece, where the minimum charge is €3.72 and the rate per km inside the city is €0.74 (O Ermis, 2020). Assuming someone makes 20 minutes of daily shared e-scooter use and given that the price of a personal reliable e-scooter in the Greek market starts approximately from €400, we can deduce that in three (3) months someone would have spent in taxis the money he/she would have spent on buying his/her own e-scooter. More or less, this should be also valid for other Mediterranean cities.

In financial terms, compared to taxis, e-scooters are always cheaper, while compared to driving a car or riding the bus, renting a scooter is probably more expensive. Nevertheless, factors such as fun and eco-friendliness can tilt the scales in favour of e-scooters. Towards awarding frequent users, some e-scooter providers offer today weekly and monthly subscription services for the unlock fee (Porter, 2019). For example, the weekly subscription service of Lime, called LimePass, is currently valid in Greece, Spain, Portugal, France, and Italy and it costs €5.99 (Skiannis, 2020b), meaning that a daily user can save €1.0 per week, as he/she will still have to pay the per-minute charge. Furthermore, some providers started recently to offer discounted rider rates to homeless or low-income people (Holman, 2019). From the cities examined in this paper, currently, this service is only available in Paris (Lime, 2019c), giving eligible participants the opportunity to save 50% or more on every Lime e-scooter ride throughout the city. In this frame, cities could require from operators to offer a) an income-based discounted payment plan to low-income customers and b) a cash-based payment plan.

What about the regulatory framework?

E-scooters were developed with legal gaps concerning their use in the urban environment, but today e-scooter sharing companies are called upon to satisfy not only their customers but also the national and local authorities. Negative publicity about e-scooters causing injuries, congesting sidewalks, discomforting pedestrians, being vandalized, and creating dangerous situations along-side traffic have driven many countries and cities worldwide to introduce and enact relevant regulations and laws (Gössling, 2020). According to media headlines for the Euro-Mediterranean region, Italy, France, Malta, and Spain have recently set specific national rules and terms on e-scooter use in urban areas, while Portugal (Perrone, 2019), Greece (Kassimi, 2019), Slovenia (Jandl & Kjuder, 2019), and Cyprus (Dimitrova, 2019) are on the way to establish relevant regulations.

In Italy, e-scooters, segways and e-vehicles (hoverboards and monowheels excluded) with a maximum power of 0.5 kW and speed below 20 km/h can circulate in urban areas and on normal roadways, like bikes, since 30 December 2019 (SmartGreen Post, 2020).

On 25 October 2019, France legalized the use of e-scooters by defining them as motorized personal movement devices, with a maximum speed limit of 25 km/h. Their users must be aged 12 or over and they can be used on cycling paths and city roads with a speed limit of 50 km/h or less, but not on footpaths, highways, and rural roads (BBC, 2019).

In December 2019, a provisional Directive from the Directorate-General for Traffic of Spain was issued for regulating the use of e-scooters in the country. This regulation set specific terms and specifications on speed limit (max 25 km/h), permitted riding areas (within 30 km/h zones, local roads, and bicycle lanes), minimum age (18 years old), fines for improper use (alcohol levels, use of headphones or mobiles, not using a helmet, riding on footpaths etc.), number of passengers (only one person per ride), and parking (in general, they should be parked in places reserved for motorcycles and bicycles) (O'Reilly, 2019).

Malta, at the end of 2019, enacted the Micromobility Regulations 2019, a detailed and structured regulatory framework for e-scooter use. The regulations introduced some novel specifications such as the one-time registration per e-scooter (each vehicle should bear a unique registration plate/sticker), the need for riders to get a relevant driving license, and the existence of a third-party risks insurance for all e-scooters. Furthermore, riders should be aged 16 or over, the maximum allowed speed on pavements is set to 10 km/hr and on urban streets and cycle paths to 20 km/hr, a helmet is not obligatory, and they may be parked on pavements or in pedestrian zones but without obstructing and restricting their prompt and safe use (The Malta Expat, 2020).

In Greece, the competent Hellenic Ministry of Infrastructure and Transport is elaborating on a new regulatory framework on the market, safety, and use of all micromobility transport modes, which is expected to be in place in the following months. According to the available information so far (Kassimi, 2019), the forthcoming legislation will characterize e-scooters as Personal Light Electric Vehicles (PLEVs) and users will be prohibited from carrying another passenger, should be over 15 years old, and should wear a helmet. Additionally, PLEVs will be further categorized according to their maximum speed as follows:

1. those with a top speed of 6 km/h (allowed to move freely in pedestrian areas),
2. those with a top speed of between 6 km/h and 25 km/h (allowed to circulate like bicycles), and
3. those exceeding 25 km/h.

In general, the aforementioned provisions follow, more or less, the arrangements set in other countries.

Although not clearly defined or foreseen in the previously mentioned regulations, we consider it appropriate to delineate the role of Mediterranean and European cities in establishing further standards and rules on e-scooter use within their jurisdictions, adapted to the local transport conditions, needs, and planning.

Preliminary data from a quantitative survey on e-scooters use in Thessaloniki, Greece.

Although this survey is ongoing and the number of responses so far represent around the 1/3 of the target number, it was considered appropriate to present some indicative preliminary findings, which are the following:

1. The majority of users are men.

2. Almost 3/4 of users are less than 35 years old.

3. Over 90% of the respondents do not own an e-scooter, but the majority of the rest ones bought their own after having tried the dockless option.

4. Students account for almost 50% of users.

5. The majority of users spend 5-10 minutes for reaching and unlocking a scooter.

6. The 1/3 of users use an e-scooter at least one day per week.

7. Instead of using an e-scooter, users would have walked (63%) and used a public bus (31%).

8. Although the majority of users prefer to ride on the existing bicycle lanes, finally they use bicycle lanes (42%), the roadway (49%), and sidewalks (9%).

9. The majority of rides last less than 10 minutes.

10. The main motivations of use are fun, time-saving, and door-to-door travel, while as main disincentives were mentioned the cost, the unavailability of e-scooters nearby, the feeling of lack of safety, and bad weather conditions.

11. Most rides take place from Monday to Friday (over 60%).

12. Almost 20% combine the use of e-scooter with public bus or walking for their trip.

13. The mandatory use of helmets is likely to decrease e-scooter use.

In summation, these preliminary results show: a) the strong acceptance of young people of this type of micromobility; b) the massive use of bicycle lanes although, in practice, a large percentage also use the roadway; c) that price and safety are the main drawbacks of use; d) that there is a notable percentage of frequent users; e) that e-scooters can favour the intermodal option; and f) that e-scooter use acts competitively to walking and public transport, without clear impact yet on car traffic reduction. Hopefully, a detailed presentation of final results will be published in the near future.

4. Integrating e-scooters in Mediterranean cities

This new transport mode is still in its infancy and cities should assess, within their own context, whether e-scooters have a meaningful and sustainable role to play. Based on worldwide experience and current regulatory practices from several Mediterranean countries, we believe that Mediterranean cities can use a broad set of tools and methodologies to regulate smoothly e-scooters and micromobility.

Moreover, the following proposals can be derived:

1. E-scooters should be considered in cities' strategic planning and outlook: Qualitative and quantitative surveys on users and use, operational consultation with stakeholders, and suitable inclusion in mobility plans like the Sustainable Urban Mobility Plans (SUMPs) are main schemes for integrating them in cities' mobility.

2. Regulating access to the market and operations once in the market: This perspective may vary to some extent from city to city, based on the overall national legislative framework and depending on the degree cities have regulatory autonomy in this issue. A national regulation should provide the basic mandatory principles on this domain, while cities should be allowed to enact locally on key micromobility topics, such as traffic management, parking, use of public space, and license or select operators through binding or non-binding agreements.

3. Gradual access to shared e-scooter market: Depending on cities' legal power to control the access of operators to the market, they can consider several options, such as no specific regulations in place, general prohibition/ban, implementation of pilot actions for testing e.g. the impact of these services on the local transport system, and set up operational permits and performance requirements.

4. Regulating actual operations and vehicles' usage: E-scooter usage, both in shared or private form, can impact public space and affect users, thus it should be regulated. Specific terms and conditions, at a local level, may cover topics such as the number of the operators and the size of their fleet, vehicles' specifications, insurance coverage, geofencing for service limitations, speed limits, dockless and docked schemes, parking and riding areas, and fines for improper use.

5. Protection of local citizens: A city may require from operators, or find a way to reward, the stability of prices during a specific operational time, safety campaigns, and operation of a local contact/support point.

6. Data utilization: Cities can require from operators to provide them with anonymized data (e.g. trips that occurred and what type of users made them) from vehicles' usage for analysing, monitoring, and planning current, and future transport practices, actions, and policies.

7. Improvement of infrastructure and public transport: E-scooters, like bikes, are transporting vulnerable road users, while the provision of inadequate spaces for parking them does not support a sustainable alternative to space-consuming cars. Traffic calming zones, cycleways and bike lanes, where also e-scooters are allowed to circulate, and dedicated parking slots can support practically the desired modal shift. E-scooter speeding could be naturally addressed if used in woonerven zones (Nalmpantis, Lampou, & Naniopoulos, 2017) also improving walkability (Gkavra, Nalmpantis, Genitsaris, & Naniopoulos, 2019). Additionally, a reliable and properly managed public transport system is the basis for sustainable urban mobility, where e-scooters may become for many people a comfortable means for reaching the public transport network and leaving their car at home.

5. Conclusions

The overall goal of this article was to outline the current situation regarding the use of e-scooters, mainly regarding the free-floating scheme, and to identify relevant challenges for providers, stakeholders, citizens, and cities in the Euro-Mediterranean area.

When such services are introduced in cities without prior consultation, or pilot applications, with local authorities and society, the provision of micromobility modes of transport might delight some but confuse others. The somehow problematic experience, which has been publicized in local media, should not let cities to deter these services and modes from contributing to their mobility landscape. The legalization, standardization, and regulation of e-scooters' use, as recently began to happen in several Mediterranean countries and cities, in terms of classification, available road space, maximum speed, and safety rules is the first step towards allowing them to claim their modal share potential in cities' mobility strategies, plans, and everyday life.

With the increasing familiarity of shared e-scooters, a dynamic increase in private ownership of such vehicles has been observed in Greece, while media reports from shared e-scooter providers show a relevant potential for several other Mediterranean cities and countries. City authorities should give time to e-scooter market and regulate it thoughtfully at an early stage (e.g. on public safety requirements, parking and no-scooter zones, users' control and fines, etc.), based on the city's current experience, lessons from peer cities, and data from existing operators. Surveys, such as the aforementioned one for Thessaloniki, Greece, and public consultation can further help cities to find ways to manage current challenges, encourage more responsible e-scooter use, and integrate these and other micromobility modes smoothly into their urban mobility strategy.

In parallel, e-scooter providers should be proactive in addressing each city's transportation concerns and urban/social attributes. This can range from providing helmets and training to users to sharing specific data with officials, researchers, and academia. Micromobility service providers and the relevant local or national authorities can work together in order to identify mobility "pain points" and priorities where e-scooters may help to address them. In our analysis, we have not been able to gather data from private micromobility service providers in order to assess users' attributes and trip distances, temporal distribution, trip purpose, and modal shift. There is, therefore, a need for research at this level to quantify and analyse these parameters. The preliminary data from an ongoing survey presented here provide some indicative trends for Greece, but they should not be used as definitive before the completion of the survey and full data analysis, which will be the following step of our research.

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Keywords

Mediterranean, micro-mobility, e-scooters, urban, sustainability, mobility.

Intelligent Transport Systems in Greece: Current Status and Future Prospects

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Abstract

This paper reviews the development and implementation of Intelligent Transportation Systems (ITS) in Greece by adopting a methodology that uses Key Performance Indicators – KPIs. Based on these indicators ITS implementation in Greece appears to perform in varying ways depending on a number of factors that relate to the local conditions in each urban area. Based on the analysis and quantification of the KPIs selected, the analysis facilitates the identification of some areas on which ITS experts and policy makers should focus for further improvement and speeder implementation. The main problems that are indicated in the study, relate to the fact the large majority of ITS projects implemented in Greece are not adequately documented and do not provide, at least to a limited extent, information over the web regarding their status or their provided services. Another problem area relates to the fact that there are no ITS projects that go beyond the road sector to encompass multiple modes of transport and support intermodality and multimodality. Also, there is a weakness identified for more ITS implementations associated with freight transport and the concept of Mobility as a Service (MaaS).

1. Introduction

Overpopulation, economic development, and the resulting need for increased mobility has been followed by negative consequences in terms of transport safety and traffic or environmental conditions (Spyropoulou et al., 2005; Hanai, 2013). This holds true especially within human settlements of increased density, taking into account, inter alia, the increasing rates of motorization (United Nations ESCAP, 2018). Intelligent Transport Systems (ITS) provide the means for efficient solutions towards the alleviation of the aforementioned challenges and contribute towards the attainment of sustainable urban transport systems and the better utilization of existing – and aging – transport infrastructure (Xiong et al., 2012; Tomas et al., 2013; United Nations ESCAP, 2018). Their vision can be summarized as forming an intelligent mobility landscape, where travellers will be fully informed, accidents and delays will be minimized, environmental impacts will be reduced, while provided services will be affordable, seamless, secure, and aware of privacy limitations (Giannopoulos et al., 2012; Lim, 2012; Kalupová & Hlavoň, 2016).

The power of ITS relies on the knowledge of the conditions prevailing within transport systems. This is achieved by collecting significant quantities of data, ranging from traffic and incident to traffic data (Smith & Venkatanarayana, 2005). These data streams enable the optimization of transport operations via several applications, such as travellers' information, traffic and incident management, and travel demand forecasting (Dabiri & Heaslip, 2018). Therefore, ITS can be perceived as a prominent symbol of smart cities, the overarching framework of which may be distilled into three main layers, namely data collection and management, data analytics, and service provision (Xiong et al., 2012; Dabiri & Heaslip, 2018). Similarly, ITS are in the heart of smart motorways which based on information received from traffic sensors and traffic cameras utilize active traffic management techniques (e.g., coordinated ramp signalling, speed and lane use management) in order to improve traffic flow, road safety, and travel reliability (Boddington et al., 2016; Jallow et al., 2019).

2. Problem statement

Despite the opportunities arising from ITS in terms of optimizing the utilization of existing transport infrastructure and alleviating significant challenges, the degree to which they can achieve their goals heavily depends on their level of deployment. The first objective of this paper is to assess the level of deployment of ITS in Greece. The assessment takes into account existing national ITS activities carried out in the context of relevant projects. The second objective includes the identification of specific areas, on which national policy makers and ITS experts should focus.

3. Methodology

The first step towards fulfilling this paper's objectives is to categorize the various ITS activities or projects conducted over time. A frequently used approach is the classification based on the priority areas suggested by the ITS Directive (2010/40/EU):

- Priority Area I: Optimal use of road, traffic and travel data;
- Priority Area II: Continuity of traffic and freight management ITS services;
- Priority Area III: Road safety and security applications; and
- Priority Area IV: Linking the vehicle with the transport infrastructure.

Several other organizations and researchers have provided classifications of ITS applications, by following either higher or lower-level approaches. An example of high-level classification may be found in the way that ERTICO (2017) discerns the ITS areas of application, namely connected and automated driving, clean mobility, transport

& logistics, and urban mobility. To the contrary, a detailed approach is that provided by Giannopoulos et al. (2012), who discern the following categories:

- Traffic and Travel Information (TTI)
- Traffic and Public Transport Management
- Navigation Services
- Smart Ticketing and Pricing
- Safety and Security
- Freight Transport and Logistics
- Intelligent Mobility and Co-modality Services
- Environmental and Energy Efficiency

Data collection in the context of this paper relies on the Greek National ITS Progress Report (Hellenic Ministry of Infrastructure and Transport, 2017) as well as the deliverable D3.1.1 of the SEE-ITS project (Katsaros & Mitsakis, 2013) in the context of which a detailed reporting concerning ITS applications has taken place. Available information is used, in order to quantify the following KPIs for the quantitative assessment of the ITS level of deployment in Greece:

- KPI1: number of ITS projects associated with each priority area
- KPI2: number of ITS projects in which the four most heavily involved stakeholders took part
- KPI3: number of involvements in ITS projects per type of stakeholder (by assuming the following types: a) central government, b) local governments and authorities, c) infrastructure operators, d) transport service providers, e) research/academia, and f) private companies)
- KPI4: number of ITS projects associated with each mode of transport (by assuming the following modes: a) road, b) rail, c) air, d) maritime, and e) multi-modal)
- KPI5: the degree to which the outputs of or at least some information for each project are available (by assuming the following values: a) "no information available", b) "limited information available", c) "complete information available")
- KPI6: number of domestic and foreign ITS projects (including national, municipal, and regional projects as well as European and cross-border projects respectively)
- KPI7: number of ITS projects per type of funding (by assuming the following types: a) private funding, b) public funding, c) private-public funding, d) EU co-funding, and e) EU funding)
- KPI8: number of ITS projects associated with urban environments
- KPI9: number of ITS projects implemented in/pertaining to each territorial unit of Greece (by adopting the first-level classification of the European Union)
- KPI10: number of ITS projects associated with each category proposed by Giannopoulos et al. (2012)

KPI1 facilitates the identification of specific priority areas that are not equally covered compared with others. While it would be beneficial to also record the amount of investment in each priority area, data limitations hinder this attempt and, thus, the provided analysis is limited to the number of implemented projects. KPI2 facilitates the identification of a centrality factor indicating the degree to which ITS projects are carried out by a wide range of stakeholders on a national scale or by certain stakeholders. This factor will derive by dividing the number of ITS projects in which a single stakeholder has taken part by the total number of projects in Greece. KPI3 allows the identification of the type of stakeholders that are more or less active in the field of ITS. KPI4 indicates the modes of transport that are supported by the carried out ITS projects. KPI5 provides an indication of whether the outputs of an ITS project are still relevant and supported by their developers. KPI6 showcases the degree to which ITS projects in Greece outreach national borders. KPI7 indicates both the nation-wide willingness-to-invest in ITS and the degree to which European funding mechanisms have been utilized. KPI8 showcases the degree to which ITS projects recognize the intensity of the problems that urban complex environments are facing. KPI9 provides an indication of the spatial distribution of ITS projects in Greece, while KPI10 sheds light on their content.

4. Preliminary results

The analysis of the literature sources mentioned in the second section resulted in the identification of 88 ITS projects in Greece. It should be noted that the quantification of the defined KPIs was not solely based on the content of these sources, but additional explorative research has taken place, in order to verify and enrich provided information. Table 1 includes the results related to KPIs 1 to 4. It is noteworthy that Greece is more active in projects related to priority areas I and II, while it seems quite inactive with respect to priority area IV. While several projects are associated with one priority area, there are also others which are associated with more than one. A prominent example constitutes the creation of ITS observatories or databases related to the process of monitoring ITS activities, which is associated with all priority areas. Similarly, projects encompassing, jointly, the installation of traffic counting devices and weather stations, the development of systems for the detection of incidents via CCTV cameras and the provision of information to drivers via Variable Message Signs (VMSs), and the operation of traffic control centres are associated with the first three priority areas. Furthermore, the four most heavily involved stakeholders are, in descending order, TrainOSE SA, the Hellenic Institute of Transport of the Centre for Research and Technology Hellas (CERTH-HIT), the Greek Ministry of Interior, and Egnatia Odos SA. By calculating the centrality factor corresponding to the most involved stakeholder (CF=16/88=0,182), it can be deduced that the implementation of ITS projects in Greece is not overly centralized, but this needs to be compared with the results

Table 1: Results related to KPIs 1 to 4: Results related to KPIs 1 to 4

KPI1	Related projects	KPI2	Projects	KPI3	Involvements in ITS projects	KPI4	Related projects
Priority area I	75	CERTH-HIT	12	Central governments	22	Road	61
Priority area II	56	Egnatia Odos SA	10	Local governments & authorities	46	Rail	14
Priority area III	18	Ministry of Interior	12	Infrastructure operators	27	Air	4
Priority area IV	6	TrainOSE SA	16	Transport service providers	28	Maritime	4
				Research/ academia	28	Multi-modal	19
				Private companies	26		

Table 2: Results related to KPIs 5 to 8

KPI5	Projects	KPI6	Projects	KPI7	Projects	KPI8	Projects
No information available	43	Domestic	75	Privately funded	27	Urban related	39
Limited information available	16	Foreign	13	Publicly funded	7	Non- urban related	49
Complete information available	29			Privately-publicly funded	8		
				EU co-funded	27		
				EU funded	19		

deriving from other countries, in order to be verified. In addition, the type of stakeholder with most involvements in ITS projects is that of local governments and local authorities, including various prefectures, municipalities, and public transport councils. The involvement of the rest stakeholders is nearly equal. Finally, the vast majority of ITS projects concerns the road sector, to a more limited extent the rail and the multimodal transport sector, and to much more limited extent the air and maritime sector.

Table 2 includes the results related to KPIs 5 to 8. The vast majority of ITS projects implemented in Greece are not adequately documented and do not provide, at least to a limited extent, information over the web regarding their status or their provided services. The unavailability of information in cases of intra-company projects funded by own resources is more excusable, but there exist cases in which various stakeholders (e.g. TrainOSE SA) announce the initiation of the provision of service, indicating their support towards that service. Moreover, Table 2 suggests that the vast majority of ITS projects in Greece is domestic, indicating a limited cooperation with foreign stakeholders. This result is mainly attributed to the fact that the list of analysed projects is exhaustive including several cases of small-scale and local projects (e.g. intelligent driver information systems regarding parking spaces within small urban districts). In contrast, it seems that a significant number of ITS projects has been financially supported from European instruments' sources. Moreover, a significant number of ITS project has been funded by own resources, which reveals a positive perception towards and willingness-to-invest in ITS. Finally, despite the significance of traffic and road safety problems within urban areas, the number of ITS projects implemented within urban environments is outweighed by those implemented at the inter-urban level.

Figure 1 includes the results related to KPI9, suggesting that the greatest number of ITS projects has involved the

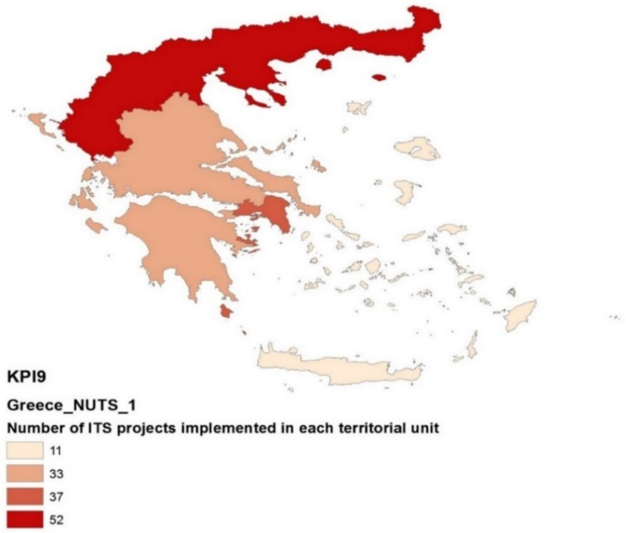

Fig. 1: Results related to KPI9

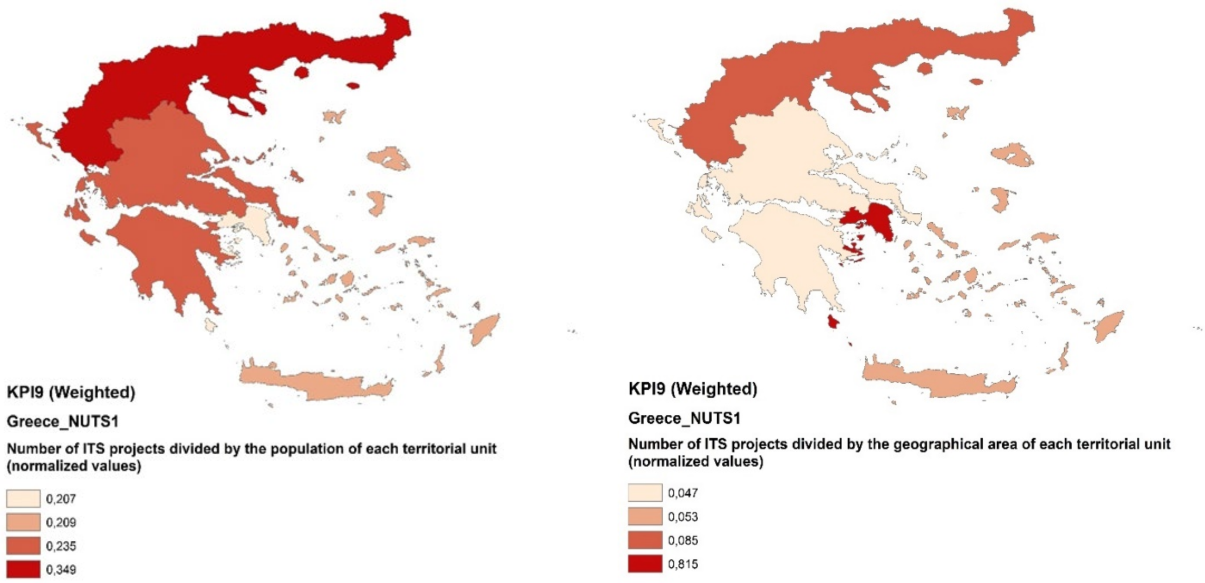

Fig. 2: Results related to KPI9 weighted by the population (left) and the geographical area (right) of each territorial unit

territorial unit of Northern Greece. This is associated with the fact that two of the most heavily involved stakeholders are in this unit (i.e., CERTH-HIT and Egnatia Odos SA). However, this result is not indicative of the density of ITS project implementation in each territorial unit. Such an assessment may be supported by weighting the number of ITS projects by the population or the geographical area of each territorial unit. According to Figure 2, the population-based approach leads to a conclusion that the densest application of ITS takes place within Northern Greece. This is attributed to the high relative number of ITS projects involving this territorial unit and its moderate population. On the other hand, the geographical area-based approach leads to a conclusion that the densest application of ITS takes place within the territorial unit of Attika. This is because said unit's geographical area is extremely lower compared to the remainders. Despite the rationale that both approaches may hold, the normalization of KPI9 based on the population of each unit seems more meaningful, considering that, as already described in the first section, increased population in urban districts is associated with several challenges that ITS aspire to alleviate. In this respect, at least for the city of Athens, the deployment of urban related ITS needs to evolve.

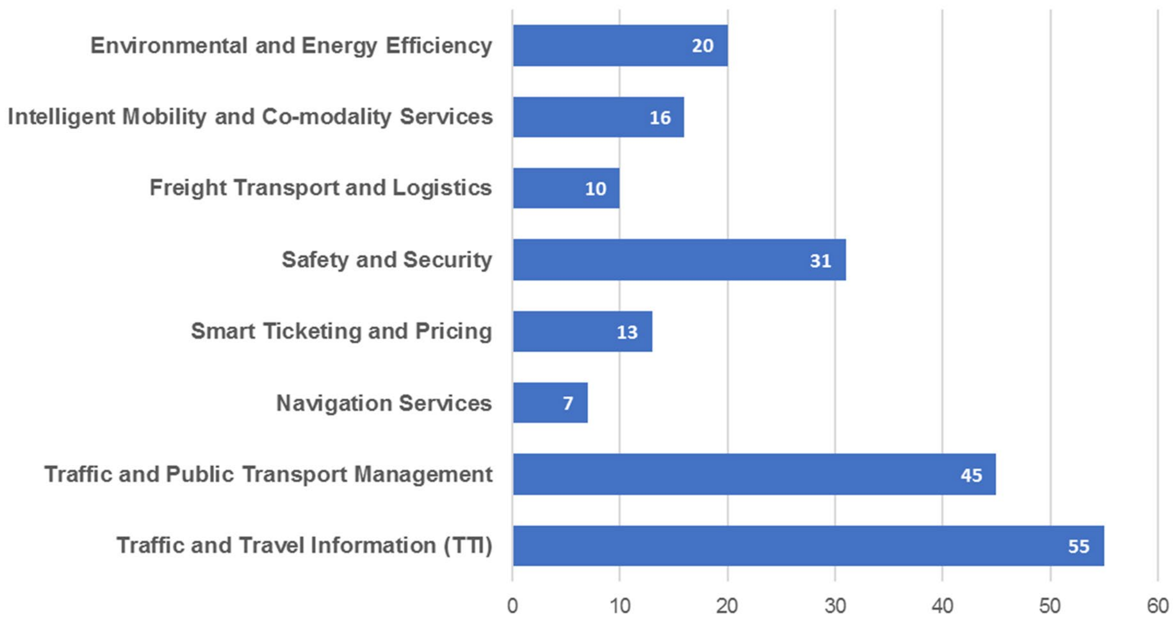

Fig. 3: Results related to KPI10

Figure 3 includes the results related to KPI10. It is noteworthy that the most projects in Greece are associated with the provision of traffic and travel information services (info-mobility) and the support of traffic and public transport management. To the contrary, the categories that are associated with the less projects are those related to the provision of navigation services, the provision of freight transport and logistics services, and the provision of smart ticketing services.

5. Conclusions

This paper constitutes an attempt to review the deployment of ITS in Greece by adopting a quantitative KPI-based methodology. While Greece appears to perform in a varying manner based on the adopted KPIs, this analysis facilitates the identification of some areas, on which ITS experts and policy makers should focus. The first area relates to the further promotion of ITS projects associated with the priority area IV of the ITS Directive. Such a recommendation is not only related with the number of projects implemented under this priority area, which may not be the most representative indicator, but also with the fact that this priority area is associated with recognized trends of the mobility sector, i.e., vehicle connectivity (KPMG, 2019; Völkers, 2019). Therefore, the promotion of projects related to this priority area is expected to lay the ground for and enhance the readiness of Greece to support Cooperative, Connected and Automated Mobility (CCAM). The second area relates to the promotion of ITS projects that go beyond the road sector, encompassing multiple modes of transport, thus supporting intermodality and multimodality. Such a goal also raises a discussion of whether the traditional emphasis of ITS service provision to lie within the road transport sector (Arndt, 2008) has yielded the expected impacts. The third area relates to the promotion of ITS projects associated with complex urban environments and the alleviation of the difficulties they steadily face, thus supporting the realization of Sustainable Urban Mobility goals. The last area, based on the results of KPI10, relates to the promotion of ITS projects associated with freight transport and the concept of Mobility as a Service (MaaS). Such a recommendation is both attributed to the key importance of logistics sector in Greece as well as the crucial principles upon which MaaS is founded including, inter alia, multimodality and intermodally, the personalization of mobility services, and their integration into common user-friendly bundles.

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Keywords

ITS, ITS in Greece, KPI, ITS implementation

EKISTICS GRID															
Created by Doxiadis as a Thinking Tool for Constructive Action, for Focusing Discussion, Classifying, Cataloguing, inspired by Geddes *Notation of Life* and *CIAM Grid*, with the added dimension of Ekistics Population Scale															
Kinds of Human Settlements:			Temporary		Villages		Polises		Metropolises		Megalopolises		National Systems		International Systems
Community Class				**I**	**II**	**III**	**IV**	**V**	**VI**	**VII**	**VIII**	**IX**	**X**	**XI**	**XII**
Ekistic Unit	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
Kinetic Field	**a**	**b**	**c**	**d**	**e**	**f**	**g**	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**
Name of Unit	**anthro pos** (human being)	**room**	**house**	**house group** (dwelling group)	**small neighbour hood**	**neighbour hood** or village	**small polis** (town or urban ecovillage**)**	**polis** (town or suburb)	**small metropolis** (large city)	**metropolis**	**small megalopolis** (conurbation)	**megalopolis**	**small eperopolis** (urbanized region)	**eperopolis**	**ecumeno polis**
NATURE - Habitat Foundations															
ANTHROPOS - Physiological/biological and social-psychological needs and constraints															
SOCIETY - Social, economic, governance and political organization															
SHELLS - the envelopes that contain settlement functions															
NETWORKS - Node-to-node systems and flows of resources, waste, data, people and information															
SYNTHESIS - Human Settlements Combined, applied, coherent design and knowledge															
EPS (Ekistics Population Scale) Doxiadis rounded figures	**1**	**2**	**5**	**40**	**250**	**1.5 T**	**10 T**	**75 T**	**500 T**	**4 M**	**25 M**	**150 M**	**1,000M**	**7,500 M**	**50.000 M**
Core Population calculated at log 7	**1**	**2**	**5**	**35**	**245**	**1.7 T**	**12 T**	**84 T**	**558 T**	**4 M**	**29 M**	**202 M**	**1,412M**	**9,886 M**	**69 B**
Population Range			3-15	16-100	101-750	751-5000	5-30 T	30-200 T	200-1,500 T	1.5 -10 M	10 - 75 M	75 - 500 M	500 - 3000 M	3 - 20 B	> 20 B
	T = Thousand; M = Million; B = Billion (thousand million). Each unit has 7 times the population of the previous unit, based on Christaller's hexagon theory.														
	Kinetic Fields a-g are the distances anthropos can walk for a given period: **A-H** are when using draft animals or vehicles.														
	Adapted by Catharine Nagashima for Ekistics and the New Habitat 2020/05/07														

Ekistics