Identification of significant metrics and indicators for smart mobility

IOP Conf. Series: Materials Science and Engineering 477 (2019) 012017 doi:10.1088/1757-899X/477/1/012017

Identification of significant metrics and indicators for smart mobility

M D Pop and O Proștean

Politehnica University of Timişoara, Automation and Applied Informatics Department, 2 Vasile Pârvan Blvd., 300223 Timişoara, România

E-mail: madalinpop20@gmail.com

Abstract. Building a better life for citizens became a motto for many cities around the world. In this context, smart city concept was defined. The aim of this concept is to make use of intelligent technologies to improve the citizens quality of life. Smart mobility is considered one out of six characteristics which compose the smart city model. The purpose of this paper is to show the significant metrics and indicators which describe the smart mobility concept. These metrics and indicators have an important role in gained performance analysis for a smart city, facilitating the comparison to other smart cities. In current paper, an analysis will be made based on these metrics and indicators to see which is their impact in smart city score setting and implicitly, in establishing the influence on the inhabitants' quality of life.

1. Introduction

In a world that is in continuing development, the transportation problem shall be a priority. Looking around, we can see how the road networks are daily overloaded. This problem, known as congestion, has a negative impact by introducing delays in traffic, which affects the time spent in traffic. In this manner people are losing hours of their life when they are going to work, shopping etc. As we can see from these daily situations, the people quality of life is affected and is required to find solutions to avoid, or reduce, the congestion problem.

The purpose of our paper is to identify the significant metrics and indicators for smart mobility concept. More than that, in our paper will be highlighted the application of standardization on identified metrics and indicators to create a generalized framework that can be easily used to compare different cities around the world from smart mobility point of view.

The structure of this paper allows us to see how important the mobility is nowadays, starting with an overview about current studies and showing the level of interest on this research domain. In the third section will be defined the traffic congestion problem and how it influences the citizens quality of life.

Section four will present the smart city concept together with its characteristics. Next section will describe the smart mobility concept, highlighting its areas, indicators and metrics. In this fifth section will be also shown the drawbacks of having a big number of metrics and indicators.

The solution for the drawbacks presented in previous section will be illustrated in section VI. Here will be shown how a standardization process applied on smart mobility metrics and indicators can lead to a general framework definition. This framework allows characterizing a city, from smart mobility point of view, using a reduced number of metrics and indicators.

In section seven will be presented an analysis of smart mobility metrics and indicators for some cities around the world. On this analysis, we will see some rankings of European smart cities and a worldwide comparison between smart city general ranking and the ranking based on smart mobility.

The final section will highlight once more that the purpose of this paper was to show which are the significant metrics and indicators for smart mobility. In the same section, the conclusions will be issued, showing the importance of having standards which permits the creation of a common framework including only the significant metrics and indicators for smart mobility.

2. Literature overview

This paper can be seen as a continuation of previous work. In [1] was made a comparison between smart city approaches, from smart mobility point of view, after smart city modelling possibilities were highlighted. There was seen how important is this smart city component in establishing the city score and were shown some potential actions that can be taken by local administration to improve the road transport management. More than that, there were presented actions taken by Romanian smart cities to maintain their position in the European smart cities ranking [1], [2].

One of the most important things in smart mobility analysis can be considered the case studies for different cities around the world [3-7]. From these studies, can be selected common factors and metrics which can be used as features for creating an informal framework for an eventual comparison between them. If we need a general framework with a reduced number of factors and metrics that should fit to each city, independently of its location, there should be defined a list of them that respects some standards and regulations [8], [9].

An interesting approach in smart city studies is presented in [10]. There is shown how important is to take into consideration the climate change problem. Giving a little attention to collected meteorological data, several proposals are issued by authors. Four aspects are considered essential to achieve a smart city planning according to necessity of giving help on global climate change fight:

- energy saving and CO_2 emissions reduction;
- predictability of possible weather disasters caused by city development or planning;
- usage of IoT (Internet of Things) technologies to create a capable system to inform citizens, in good time, in case of a natural disaster will be produced;
- create a complex system that uses sensors placed in the city to monitor weather changes in comparison with urban planning and can give advices for some adjustments in the city planning, to prevent natural disasters.

A new category of studies that shall be mentioned, are the studies concerning the concept of smart mobility from urban planner point of view. At this level, cities can be characterized in terms of sustainable mobility using the concept of PCA (Principal Component Analysis) [11]. The first step on this analysis was to select a sample that includes several cities. Previous step was followed by a selection of relevant data for the studied cities which will lead to obtaining PCA factors. Authors considered next PCA factors, in order of their importance:

- inverse index of smart mobility;
- index of eco-mobility;
- index of car-free mobility.

In the same category of studies, as previous one, can be included the study based on new urbanism and compact city concepts [12]. New urbanism concept is very interesting because it puts on first place the people mobility as pedestrians instead of mobility as car drivers. This vision advocates to good connections between neighborhoods, walkability and quality architecture. Another concept presented is related to city compactness which promotes the car dependability reducing in favor of walkability, bike and public transportation usage.

3. Traffic congestion – problem definition

Traffic congestion can be defined as a situation that we experience daily, in many cities around the world, which is characterized by increased travel times, slower speeds and long queues of vehicles at the intersection entering point. If we look to a long-term evolution of transportation, the occurrence of this problem in road traffic has a negative impact on quality of life. It influences the environment, daily activities, different provided services and moving of goods.

A lot of studies are made on traffic congestion reducing field. Solutions as using LSTM (Long Short-Term Memory) networks, part of RNN (Recurrent Neural Networks), for traffic flow prediction are provided by scientists [13]. A more complex traffic management system, involving vehicles detection sensors, data analysis tool and traffic congestion prevention algorithm is presented in [14].

4. Smart city concept

Smart city concept is a complex system that has as final scope the citizens quality of life improvement. To achieve this goal is necessary to have a great involvement of local administrations through city development decision-making process. More than that, there is the need of an active involvement of citizens, helping in the application of local administrations decisions, or easier, by giving feedback to them.

A city can be considered smart if it respects some rules and achieves some defined goals. To a better understanding of how this concept is applied to a city, several modelling approaches were proposed. The most popular way to model a smart city is using Giffingers' approach [1], [2]. In this case, smart city can be seen as a combination of six characteristics, as it is illustrated in Figure 1. For each characteristic are attached several factors which will give the scores, for evaluated cities, to add them to smart cities ranking. We can see that is necessary to have an equilibrium between these characteristics to ensure a high quality of life for citizens.

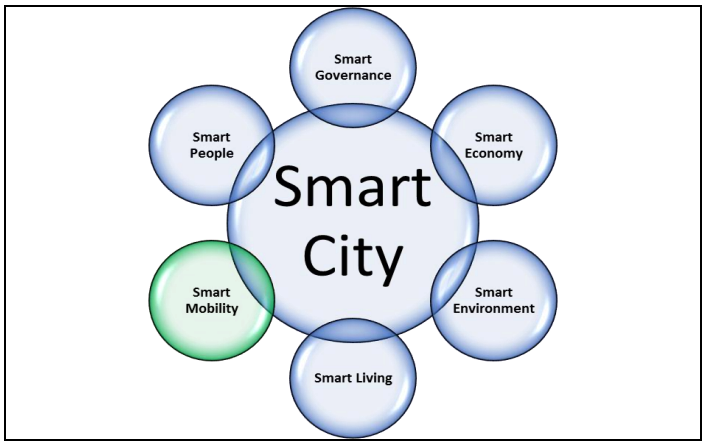

Figure 1. Smart city model based on Giffingers' approach

A good measure in quality of life improvement is to use the resources efficiently, to obtain the wastes and CO_2 emissions reduction. As Lattore-Biel mentioned in [5], we can observe the impact of traffic and transportation activities in the use of resources, leading to an increasing of noises, wastes and CO_2 emissions, which have a direct impact on our daily life.

Further, this study will be oriented to smart mobility concept definition and analysis of its components.

5. Smart mobility

Part of smart city concept, smart mobility has a big impact on cities ranking because it can influence other four characteristics: smart people, smart economy, smart environment and smart leaving. A smart mobility system includes the road infrastructure, the means of transport, the polices and

regulations that are ensuring a good traffic flow in the city, with reduced travel times and CO_2 emissions.

After an analysis of relevant studies on smart mobility field, we propose the architecture from Figure 2 to describe how smart mobility concept can be applied to a city. In this case, using systems decomposition property, we can identify three levels of abstraction.

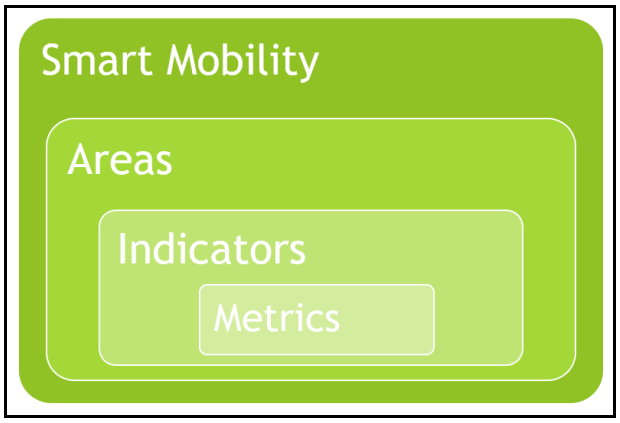

Figure 2. Smart mobility system architecture

First level of abstraction is represented by the general areas of interests that can give an overview of how is applied the smart mobility concept, such as: system management characteristics, application of intelligent technologies etc. Next level of abstraction is referring to some indicators that are specific for each area. These indicators are generally used to describe how smart is a city from mobility point of view and we can find them in many studies. The third level is represented by the metrics, which gives the potential ways of action to improve the current smart city score and implicitly the citizens quality of life.

Further we show an analysis of indicators of indicators and metrics for smart mobility, taking into consideration previous studies [1], [3-7], [12]. These indicators and metrics were tailored to the architecture proposed in Figure 2. We considered three areas as the most relevant to describe the smart mobility of a city. For each area, will be presented the indicators and metrics that were common in analysed studies.

One of the most relevant areas, which is illustrated in Figure 3, is the accessibility. Indicators as public transport, car sharing and rail networks define how easy people can reach their desired destination, saving time, money and protecting the environment. As important metrics shall be mentioned the ratio between demand and supply, the existence of special lanes for public transportation system and the covering routes.

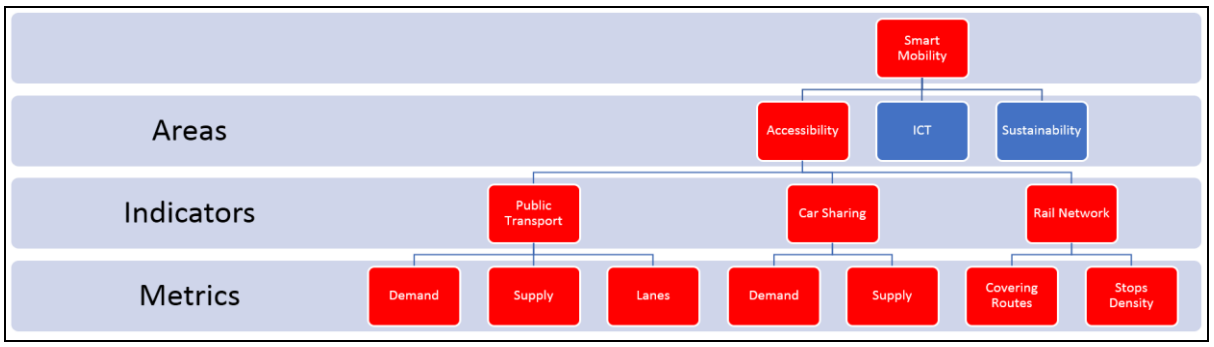

Figure 3. Accessibility area – indicators and metrics

Another area of interest is the ICT (Information and Communication Technology) and is shown in Figure 4. In this area are included as indicators the traffic coordination, SMS (Short Message Service) and electronic systems. A metric for traffic coordination is the traffic signals system, from intelligent green intervals scheduling point of view, case in which these timings are automatically updated based on real-time traffic data. Another metrics for traffic coordination are the variable message signs and routing applications, which are also related to real-time traffic status. SMS indicator includes metrics as traffic alerts and parking payment using this service. On electronic systems indicator category are included special devices which provide the opportunity of buying travel tickets for public transport or parking payment. Electronic systems can be also used as bus stop signs, general traffic signs or for showing messages as advices for alternative routes.

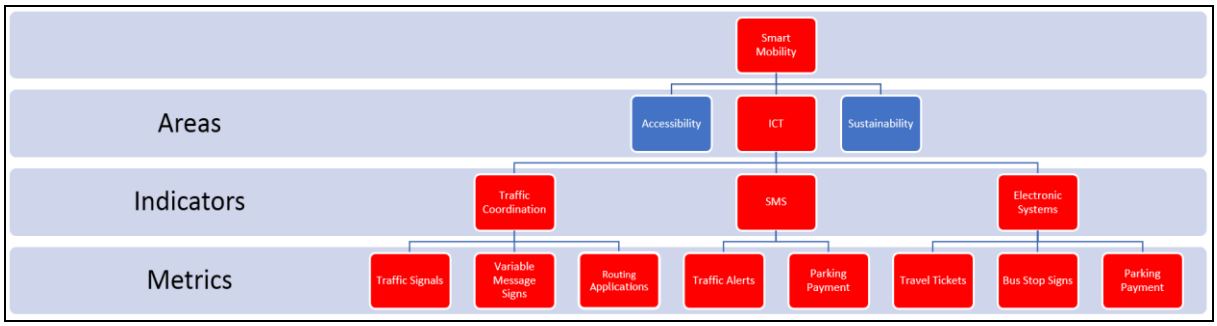

Figure 4. Information and Communication Technology (ICT) area – indicators and metrics

The last, but the most important area of smart mobility, is the sustainability (Figure 5). Here, were found as the most studied indicators the ecological fuels, bike sharing programs and the special zones that are existing in a city. As part of ecological fuels, we can mention as metrics the electric, natural-gas and LPG (Liquefied Petroleum Gas) buses provided by public transportation system. The sustainability indicator that is related to bike sharing, is ensured by a proper ratio between supply and density of bike sharing stations. Restricted zones indicator is referring to the transformation of some city zones to restricted for vehicles, known as pedestrian areas. In the same category of special zones is included the assurance of special lanes for bikes.

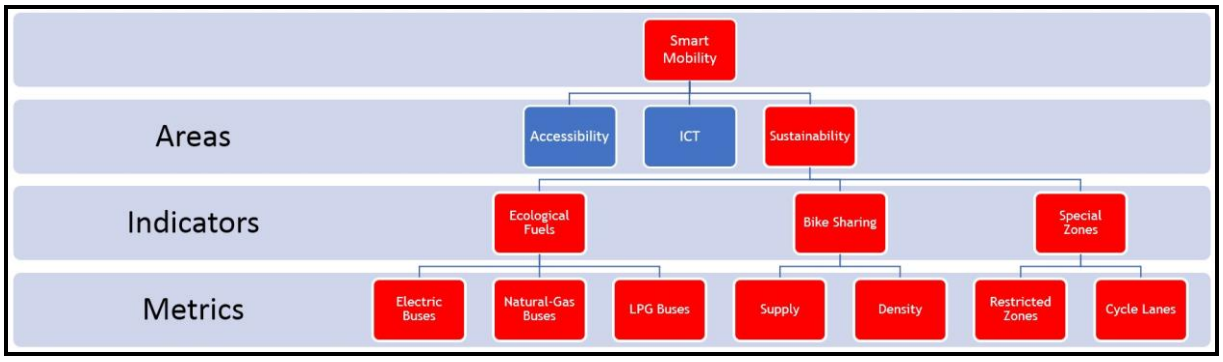

Figure 5. Sustainability area – indicators and metrics

6. Standardized metrics and indicators

As we seen before, there are many metrics and indicators to characterize a city from smart mobility point of view. It is needed to have a common framework which can make possible to select only some relevant metrics and indicators. This approach will simplify the comparison procedure between many cities around the world.

The solution for relevant metrics and indicators selection came through a standardization process. The ISO 37120:2014 standard defines indicators for a sustainable development of communities, with focus on quality of life improvement and quality of city services. ISO 37120:2014 approach is to define two categories of indicators: core indicators and supporting indicators, for each theme of interest, according to services and areas of application provided by the city. Core indicators are considered the relevant indicators which shall be followed to manage and evaluate the city services and citizens quality of life. The main difference between core indicators and supporting indicators is that the first type of indicators is considered as required to demonstrate the quality of services and quality of life provided by a city, while the second category of indicators is represented by some recommendations that should demonstrate the same features [9].

In Table 1 we can find the core and supporting indicators related to smart mobility according to [9]. As we mentioned before, we consider that smart mobility can be characterized as a mixture between four themes: environment, fire and emergency response, recreation and transportation.

Table 1. Significant indicators for transportation according to ISO 37120:2014

Theme	Core indicators	Supporting indicators
Environment	Fine Particulate Matter (PM2.5) concentration	Noise pollution
	Particulate Matter (PM10) concentration	O_3 (ozone) concentration
Fire and emergency response		Response time for emergency response services from initial call
		Response time for fire department from initial call
Recreation		Square metres of public outdoor recreation space per capita
Transportation	Kilometres of high capacity public transport system per 100 000 population	Percentage of commuters using a travel mode other than a personal vehicle
	Kilometres of light passenger public transport system per 100 000 population	Number of two-wheel motorized vehicles per capita
	Annual number of public transport trips per capita	Kilometres of bicycle paths and lanes per 100 000 population
	Number of personal automobiles per capita	Transportation fatalities per 100 000 population
		Commercial air connectivity (number of non-stop commercial air destinations)

A very good approach of a relevant set of indicators for the smart mobility areas of interests are proposed by Giffinger et al. [2]. The list of significant metrics and indicators for smart mobility, based on mentioned approach and tailored to our proposed method of smart mobility concept decomposability, can be found in Figure. 6.

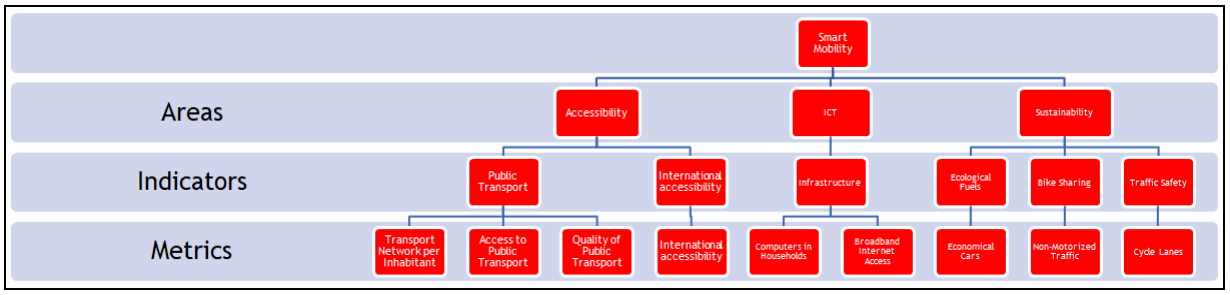

Figure 6. Common framework for smart mobility – indicators and metrics

7. Smart mobility worldwide analysis

Smart mobility metrics and indicators have a significant impact on smart cities ranking. In Table 2 we can see the top 5 European smart cities, from medium-sized cities perspective (100 000 to 500 000 inhabitants), according to [2]. In current analysis, we considered the scoring for each smart mobility area. The corresponding values for accessibility were obtained by summing up the indicators values for local accessibility, representing the public transport, and international accessibility.

Table 2. Top 5 European smart cities based on smart mobility – areas values

Rank	City	Country	Accessibility	ICT	Sustainability
1	Eindhoven	Netherlands	1.862	1.537	-0.276
2	Salzburg	Austria	2.382	0.354	0.077
3	Aarhus	Denmark	2.006	1.050	-0.293
4	Luxembourg-Ville	Luxembourg	2.672	0.622	-0.629
5	Leicester	United Kingdom	1.195	0.200	0.909

Looking from a worldwide perspective, we can see in Table 3 a top 10 worldwide smart cities. To see which is the impact of smart mobility on smart city scoring, for each city was attached its smart mobility ranking, according to [15], based on Cities in Motion Index (CIMI). In this case, were studied 165 cities. We can see some big differences in top 10 between smart city and smart mobility rankings. Singapore is on the 6th place as smart city and on 63rd place from smart mobility point of view. The biggest difference is on Hong Kong case, where the smart city ranking puts it on the 9th place and smart mobility on the 87th place.

The observed differences can be explained through better results of the metrics and indicators from the other smart city characteristics, that were presented in the on 2nd section of this paper.

Table 3. Top 10 worldwide smart cities based on CIMI scoring

Smart city ranking	City	Country	Smart mobility ranking
1	New York	United States of America	4
2	London	United Kingdom	2
3	Paris	France	1
4	Tokyo	Japan	22
5	Reykjavik	Iceland	7
6	Singapore	Singapore	63
7	Seoul	South Korea	3

8	Toronto	Canada	68
9	Hong Kong	China	87
10	Amsterdam	Netherlands	13

8. Conclusion

This paper has as starting point the presentation of traffic congestion problem that affects many cities around the world. This situation, that appears in daily road traffic has a negative impact on environment and on people quality of life by increasing travel times, vehicle queues on the road network and CO_2 emissions level. A solution for this worldwide problem can be considered the usage of smart city concept, especially the concept of smart mobility.

Smart mobility is a concept that starts to be used by many local administrations to increase the citizens quality of life by reducing traffic congestion and offering an intelligent framework to optimize the traffic flow in intersections. In this paper are identified the metrics and indicators that are characterizing the application of smart mobility concept. The most important thing that derives from the initial analysis, is the necessity of having a common framework that allows us to make a better comparison between different cities around the world, from smart mobility point of view.

The purpose of this paper was to identify the significant metrics and indicators for smart mobility and this was possible only by applying standardization, even if is not completely applied, being tailored to city necessities. ISO 37120:2014 defines these metrics and indicators and can be easily applied to each city and can offer an overview of the decisions that shall be taken by local administrations, or countries governments in some cases, to increase the smart mobility level.

References

[1] Pop M D and Proștean O 2018 *A Comparison Between Smart City Approaches in Road Traffic Management*, 14th International Symposium in Management 2017 (SIM), Timisoara, Romania, October 27-28, pp 29-36

[2] Giffinger R, Kramar H, Haindlmaier G and Strohmayer F 2015 *European Smart Cities*, Available at: http://smart-cities.eu/ [Last accessed on July 28, 2018]

[3] Battara R, Zucaro F and Tremiterra M R 2017 *Smart mobility: An Evaluation Method to Audit Italian Cities*, 5th IEEE International Conference on Models and Technologies for Intelligent Transportation Systems 2017 (MT-ITS), Naples, Italy, June 26-28, pp 421-426

[4] Hong D and Wong L W 2017 *A Study on Smart Mobility in Kuala Lumpur*, 2nd International Conference on Computing and Communications Technologies 2017 (ICCCT), Chennai, India, February 23-24, pp 27-32

[5] Latorre-Biel J I, Faulin J, Jiménez E and Juan A A 2017 *Simulation Model of Traffic in Smart Cities for Decision-Making Support: Case Study in Tudela (Navarre, Spain)*, 2nd International Conference Smart-CT 2017, Málaga, Spain, June 14-16, pp 144-153

[6] Nor N M and Wahap N A 2014 Workforce mobility: Contributing towards smart city, *IOP Conf. Ser.: Earth Environ. Sci.* **18** 012168

[7] Roda M, Giorgi D, Joime G P, Anniballi L, London M, Paschero M and Mascioli F M F 2017 *An Integrated Methodology Model for Smart Mobility System applied to Sustainable Tourism*, IEEE 3rd International Forum on Research and Technologies for Society and Industry 2017 (RTSI), Modena, Italy, September 11-13, pp 130-135

[8] ***European Commission 2012 *Smart Cities And Communities -European Innovation Partnership C(2012) 4701 final*, Brussels, Belgium, July 10, Available at: http://ec.europa.eu/transparenc y/regdoc/rep/3/2012/EN/3-2012-4701-EN-F1-1.PDF [Last accessed on July 28, 2018]

[9] ***International Organization for Standardization 2014 *ISO 37120:2014 - Sustainable development of communities -- Indicators for city services and quality of life*

[10] Deng D, Zhao Y and Zhou X 2017 Smart city planning under the climate change condition, *IOP*

Conf. Ser.: Earth Environ. Sci. **81** 012091

[11] Papa R, Gargiulo C and Russo L 2017 *The Evolution of Smart Mobility Strategies and Behaviors to Build the Smart City*, 5th IEEE International Conference on Models and Technologies for Intelligent Transportation Systems 2017 (MT-ITS), Naples, Italy, June 26-28, pp 409-414

[12] Varma G R 2017 *A Study on New Urbanism and Compact City and their Influence on Urban Mobility*, 2nd IEEE International Conference on Intelligent Transportation Engineering 2017 (ICITE), Singapore, Singapore, September 1-3, pp 250-253

[13] Zhong Y, Xie X, Guo J, Wang Q and Ge S 2018 A new method for short-term traffic congestion forecasting based on LSTM, *IOP Conf. Ser.: Mater. Sci. Eng.* **383** 012043

[14] Rath M 2018 Smart Traffic Management System for Traffic Control using Automated Mechanical and Electronic Devices, *IOP Conf. Ser.: Mater. Sci. Eng.* **377** 012201

[15] Berrone P and Ricart J E 2018 *IESE Business School - IESE Cities in Motion Index*, **ST-471-E**, pp 24-36