Towards a Technological Platform for Transparent and Flexible Assessment of Smart Cities

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Abstract: The concept of smart cities is widely accepted as a powerful tool to improve living standards in all city dimensions. Smart cities aim to provide better quality services in the field of health, transport, energy and education in order to increase the comfort of their citizens. Whether in the planning or implementation phase, a key success factor for building smart cities is measuring the productivity of the decisions and obtaining an assessment of the final results. Most cities perceive the smart city concept, many of them are working on strategies for its implementation and more and more of them take concrete actions for deployment of “smart” solutions. Two questions arise from this: “What are the challenges to become a smart city?” and “What the city undertakes to become smart?”. Their answers required assessment of the of city’s “smart services” and the social effect of deployment of “smart solutions” during the transformation from “smart” plan to “smart” process. In such a context, this paper proposes an architecture of technological platforms for assessment of city’s “smartness”. Its primary goal is to provide a transparent and flexible indicator framework that supports quantitative progress evaluation of smart city strategy implementation, feedback on efficiency of current policies, timely and informed decision making and increased understanding of future city challenges. The main building components of the platform, namely repository, web APIs and web user interface, are described. Additionally, a classification schema of indicators covering six main thematic areas is proposed.

1 INTRODUCTION

European cities are forerunners in the transition towards a low carbon and resource efficient economy. A fast-growing percentage (currently 72%) of the EU population lives in urban areas, using 70% of energy. Quality of city life and the attractiveness of cities as environments for learning, innovation, doing business and job creation are now key parameters for success in the global competition for talent, growth and investments. Key challenges for realizing the vision of “Smart and Sustainable Cities” are to provide solutions to significantly increase cities' overall energy and resource efficiency through actions addressing the building stock, energy systems, mobility, climate change, water and air quality. Such actions should bring profound economic, social and environmental impacts, resulting in a better quality of life (including health and social cohesion), competitiveness, jobs and growth.

EC defines Smart Cities as places where the traditional networks and services are made more efficient with the use of digital and telecommunication technologies, for the benefit of their inhabitants and businesses (EC, 2013). In Smart Cities, digital technologies translate into better public services for citizens, better use of resources and less impact on the environment. Big Data has become crucial for fulfilling the vision of smart cities - sharing information is the key enabler in the transition of a city becoming smart (Gulisano, 2004). The ability to harness real-time, highly granular data across a wide range of city operations and services is changing the way citizens manage and experience the urban environment. For this reason, the benefits offered by Big Data are a key element of many smart city strategies.

Availability of data and the access to data sources in cities are paramount. There is a broad range of data types and data sources: structured and unstructured data, multi-lingual data sources, data generated from machines and sensors, data-at-rest and data-in-motion. Value is created by acquiring and combining data from different sources and providing access to it with low latency while ensuring data integrity and preserving privacy. Pre-processing, validating, augmenting data and ensuring data integrity and

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accuracy also add value. At the same time, this heterogeneity of sources and types creates a number of challenges associated with Big Data use in a Smart City such as volume, velocity, variety, veracity and value.

Powerful data techniques are needed, to allow collecting, storing, analyzing, processing, and visualizing vast amounts of city related data. Handling highly variable and real-time datasets requires new tools and methods, such as powerful processors, software and algorithms, that go beyond traditional "data mining" tools designed to handle mainly low-variety, small scale and static datasets, often manually. Key aspects such as real-time analytics, low latency and scalability in processing data, new and rich user interfaces, interacting with and linking data, information and content, all have to be advanced to open up new opportunities and to sustain or develop competitive advantages. Interoperability of data sets and data-driven solutions, as well as agreed approaches are essential for a wide adoption within and across city authorities and citizens.

A great tool for policy making, decision support and performance assessment in fields such as environment, economic, mobility, are indicators and composite indexes. The indicators allow better understanding of smart city challenges by stakeholders and highlight the effective policies, best practices and reasonable decisions. The composite indexes can be unambiguously undestanded by the policy makers and easily communicated to the general public (Bohringer, 2007). Both indicators and composite indexes should be developed with a clear vision of how they interact with each other, otherwise the policy decisions could decrease the opportunities for long-term sustainability (Mayer, 2008).

All these demand rethinking technologies around smart city solutions and bring the main objective of project “Big Data Innovative Solutions for Smart Cities” (Big4Smart, 2018), funding by the National Scientific fund of Ministry of Education and Science in Bulgaria. The primary goal of Big4Smart project is *to develop methodology, implemented by an open technological platform, that support making informed and timely decisions on big data for building smart cities*. This paper proposes ***an architecture of the technological platform*** for Big4Smart project that provides ***a transparent and flexible performance assessment of smart cities through a range of indicators covering all city aspects*** such as living, people, transport, etc. The indicators give an insight into the extent to which the city is becoming “smarter” and outline the driving factors for sustainable development.

The purpose of the indicators directly influences their selection. Since they are used for assessment of cities’ performance and to inform policy at the city level, it is important to define them in national context, taking into account the national conditions and priorities. In addition, the availability of data sources is a critical issue for successful calculation of indicators’ values. The required data is provided primary at national level by variety of institutions such as national statistical offices, ministries and government agencies, non-government organizations, etc. Thus, although the Big4Smart methodology aims to provide a smart city evaluation concept in general, its underlying technological platform should be developed in national scope, namely taking into account the Bulgarian context.

The rest of the paper is organized as follows. The current state of the research on the problem area is described in Section 2. The architecture of the Big4Smart platform is described in Section 3. Section 4 is devoted on indicator classification schema, adopted to the Big4Smart platform. Conclusions and directions for future work are outlined in Section 5.

2 STATE-OF-THE-ART

Several indicator frameworks related to performance evaluation of smart cities are developed within European Framework programs. Their main drawbacks could be summarized as follows:

- Covering a specific city sector such as healthcare, education, industry, etc.;
- Assessment of current performance state without any insight into progress to "smartness".

To the best of our knowledge there is no indicator framework for evaluation of smart city performance in Bulgaria. In addition, the proposed Big4Smart platform aims to assess the progress of cities by covering variety smart city dimensions in six thematic areas: smart mobility, smart nature, smart living, smart people, smart economy and smart government, described further in Section 4.

2.1 State-of-the-Art at European Level

There are a lot of undergoing FP7 and Horizon 2020 projects and research initiatives related both to Big Data and Smart Cities. Table 1 lists several ones very relevant to Big4Smart research. It is advisable to keep all the given values.

Table 1: State-of-the-Art at European level.

EIP-SCC Market Place	***Description:*** The EIP-SCC Market Place is an initiative supported by the European Commission that aims to develop and implement integrated smart city solutions, accumulate knowledge and facilitate exchange of information and focus on the intersection of Energy, ICT and Transport.
	Relation: Big4Smart is especially interested in the activities of Integrated Infrastructures & Processes (including Open Data), Sustainable Districts and Built Environment and Sustainable Urban Mobility action clusters that exploit Big Data to provide energy, transport and ecology solutions in the urban context.
Big Data Europe	***Description:*** Big Data Europe builds innovative multilingual products and services based on semantically interoperable, large-scale, multi-lingual data assets and knowledge, available under a variety of licenses and business models.
	Relation: The methods and tools related to Big Data analytics that are targeted at use of mobility data coming from multiple sources, transport data exploitation, energy grid data, etc. are of special interest to the work of Big4Smart.
SMARTIE	***Description:*** SMARTIE develops a distributed framework to share large volumes of heterogeneous data in smart-city applications.
	Relation: Big4Smart looks into the distributed framework and its operation based on where these volumes of smart city information are flowing and where they should be (pre-) processed and analysed.
Open Cities	***Description:*** EU CIP Open Cities project that aims to validate Open Innovation methodologies to the Public Sector Future Internet Services for Smart Cities. It uses platforms in Crowdsourcing, Open Data, Fiber to the Home and Open Sensor Networks in seven major European cities.
	Relation: Big4Smart investigates the Pan European Open Data Platform developed within Open Cities, in order to use the various sets of data for the project methodology validation.
FIWARE	***Description:*** FIWARE is an EU driven middleware platform for development and global deployment of Future Internet applications. FIWARE Lab deploys a geographically distributed network of federated nodes leveraging on a wide range of experimental facilities. FIWARE provides specific enablers for data and smart cities management.
	Relation: FIWARE Lab and infrastructure will be used by Big4Smart to test the project methodology and for the use cases to be developed, exploiting Open Data published by cities and other organizations that is made available in the Lab. Big4Smart investigates the provided by FIWARE Big Data and Smart City related enablers.
FINESCE	***Description:*** FINESCE (Future INtErnet Smart Utility ServiCEs) is the smart energy use case project under FI-PPP EU FP7 that contributed to the development of an open IT-infrastructure related to the energy sector. The project organized and run a series of field trials in 7 European cities
	Relation: Historical Smart Energy datasets from the FINESCE trial sites are available as open data and will be used in Big4Smart methodology validation. Furthermore, Hybrid Cloud Data Management component that provides interface with private and public data storage platforms is of special interest for Big4mart.

2.2 State-of-the-Art at Bulgarian Level

In the recent years Big Data and Smart Cities challenges have become a research topic for Bulgarian academy, public administration and industry. Research endeavours are not isolated at national level but are taken in collaboration with leading EU and world research teams and organizations. Even though the obtained results are promising, they are still providing just limited solutions related to specific aspects and do not realize a more holistic approach and methodology that is targeted by Big4Smart. Table 2 shows a summary of the current research initiatives in the area and description on how Big4Smart plans to leverage beyond.

Table 2: State-of-the-Art at Bulgarian level.

SMARTER TOGETHER	***Description:*** H2020 SMARTER TOGETHER aims at large-scale replication and at in-depth knowledge transfer about setting up of Smart City business models and citizen-centric innovation contributing to positive societal dynamics. **Bulgarian partner:** Sofia city
	Relation: Big4Smart investigates the SMARTER TOGETHER Data Platforms, the integrated new datasets from energy and mobility, as they all provide Open APIs that can be easily extended of data analysis.
mySMARTLife	***Description:*** mySMARTLife H2020 project is developing and testing integrated innovative solutions in the 'lighthouse cities' focuses on high performance district (smart homes, smart buildings, renewables, district heating and cooling); smart grids and mobility (electric vehicles, smart charging infrastructure). ***Bulgarian partner:*** Varna city
	Relation: The project deploys an extensive monitoring and evaluation programme to assess the effectiveness of mySMARTLife actions and interventions. Contacts have already been established by the team to apply Big4Smart methodology in the mySMARTLife integrated planning and decision-making process.
Sharing Cities	***Description:*** Sharing Cities is a H2020 project offers a framework for citizen engagement and collaboration at local level, thereby strengthening trust between cities and citizens. ***Bulgarian partner:*** Bourgas city
	Relation: Big4Smart investigates the developed by Sharing Cities technologies to manage data from a wide range of sources, including sensors, and will built upon them.
	Description: H2020 SmartEnCity, aims to develop a systemic approach and strategies for transforming European cities into sustainable, smart and resource-efficient urban environments. Bulgarian partner: Asenovgrad city
	Relation: Big4Smart investigates the mechanisms for data analysis for integrated planning of measures to reduce energy demand and maximize renewable energy supply.

Table 2: State-of-the-Art at Bulgarian level. (cont.)

PLEEC	***Description:*** By combining best practices, FP7 PLEEC (Planning for energy efficient cities) develops a general model for energy efficiency and sustainable city planning. ***Bulgarian partner:*** Ruse city
	Relation: The model developed by PLEEC is based on an intensive analysis of vast amounts of heterogenous data, which is of special interest to Big4Smart developments.
DaPaaS	***Description:*** The project combines data-as-a-service theories with use of open and linked data to improve linked open data access. The goal is to reduce the barriers of insufficient resources and allow citizens and public bodies to contribute to the open data and expand the linked open data cloud. ***Bulgarian partner:*** Sirma and Ontotext
	Relation: The project is more focused on linked open data and its management, rather than on the analysis of Big Data. Nevertheless, the Big4Smart investigates the developed DataGraft tool, which accelerates and simplifies the linked open data publication, consumption and reuse cycle.

3 Big4Smart ARCHITECTURE

The architecture of the Big4Smart platform is presented in Fig.1. It has three main building components, namely repository, web APIs and web user interface.

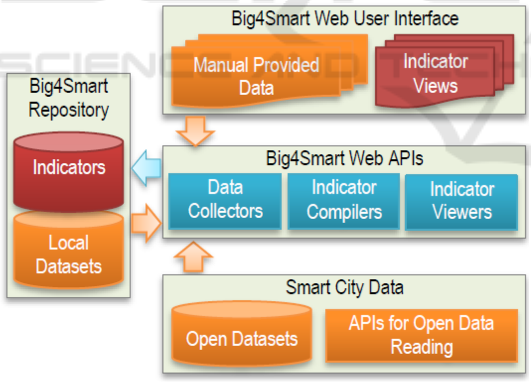

Figure 1: Big4Smart Architecture.

Big4Smart Repository stores datasets needed for calculation of indicators' values, metadata for indicators as well as indicators' values themselves. Both automatic and manual data collection is supported. The automatic data collection is based on open datasets and external APIs that provide access to such datasets. In the Republic of Bulgaria National Reform Programme aligned to the strategy "Europe 2020" is included an initiative for establishment of open data (Strategy "Europe 2020"). At European level, the open data are regulated by the Directive 2001/29/EC of the European Parliament and of the Council of 26 June 2013 amending Directive 2003/98/EC on the re-use of public sector information (Directive 2003/98/EC). The law of access to the public information carries this directive in Bulgarian legislation. In this regard, Republic of Bulgaria open data portal is functioning since 2014. Thus, a source of data for calculating the indicators are the existing open datasets. A large share of useful data is stored internally in cities' departments. Often, such data is not easily localizable and sometimes it is not in machine readable format. In addition, not all published open data satisfies the common accepted principles of open data and specific data needed for calculation of indicators' values could be missing. Thus, a *Web User Interface* for structuring new datasets is provided.

The *Big4Smart web APIs* consists of three groups of services:

- *Data Collectors* – read datasets needed for indicator calculation;
- *Indicator Compiles* – calculate values of indicators;
- *Indicator Viewers* – support indicator visualization.

Data Collectors are responsible for gathering data, which can be available open datasets, non-open datasets, provided by stakeholders, data form additional sources such as online questionnaires, existing smart city platforms, etc. Since the calculation of single indicator could requires aggregation of data from multiple datasets, the data collectors adopt the Linked Data approach for interlinking and attribute mapping between datasets. The linked data sets allow heterogenous data to be combined in a unified coherent source and usage for "smart", data-driven decision making.

The calculation of indicators' values is provided by *Indicator Compilers* services of Big4Smart web APIs. Depending of the type of the output from calculation, there are three types of indicators:

- *Number* – an absolute numerical value, for example the concentration of carbon dioxide emissions in µg/m3.
- *Rate* – a value, typically calculated in percentages, for example the percentage of the population affected seriously by crime or traffic accidents.
- *Value on a scale* – an integer value obtained through qualitative assessment, for example an assessment of the extent to which citizens may participate in environmental decision-making in scale of 0 to 10. A widely adopted approach is application of Likert scale described qualitatively.

The calculation of indicators' values is performed by preliminary defined formulas and/or algorithms that are implemented as operations of data compiles services. The calculation process includes the following steps, shown in Fig. 2:

1) *Specification of indicator(s)*, which value(s) should be calculated through web user interface, for example calculate Access to public transport;
2) *Checking needed data* for calculation, for example collect the number of inhabitants with a transportation stop within 500 m and the total population by Indicator Compilers;
3) *Checking available data* for calculation by Data Collectors;
4) *Retrieving data* for calculation by Data Collectors (if step 3 is successfully performed, otherwise sending notification to the end user);
5) *Passing data* to Indicator Compilers;
6) *Calculation* based on related algorithms by Indicator Compilers, for example (number of inh/total population) x 100;
7) *Visualization of indicator(s)' value(s)* by Indicator Viewers.

The quotative values of the indicators provide a possibility for their visualization on the web user interface. The visual presentation is supported by Indicator Viewers services of Big4Smart web APIs, providing different visualization models. It is especially important for effective perception of obtained assessments by the stakeholders. The visualization provides not only graphical data representation, but "smart" interaction with the users. It is widely adopted by companies such as Google, Facebook, Amazon, Apple, Twitter and Netflix to support decision making.

4 CLASSIFICATION SCHEMA OF INDICATORS

The classification schema of indicators is elaborated as a result of systematic literature review, covering four major reference electronic databases provided by IEEE, ACM, Elsevier and Springer (Petrova-Antonova, 2018). Additionally, a manual web search is performed using Google and Bing search engines. The collected indicators are explored in terms of property that is measured or observed, primary purpose, approach of calculation, unit and type of assessment. As a result, six thematic areas of classification schema are identified: Smart Nature, Smart Living, Smart Mobility, Smart Governance, Smart People and Smart Economy.

The *Smart Nature* thematic area asses the city impact on the environment and its environmental resilience. The pollution, the supply and efficiency usage of resources (energy, water, land, etc.) are analysed, as well as the activities to build a green environment are considered in this thematic area. The cities face complex and multi-dimensional challenges during smart transformation process. Therefore, *Governance* mechanisms are required to facilitate the creation and implementation of effective public policies. Building of a smart city needs more than just concentrating on a few specific problem areas in a piecemeal approach to policy. It requires a set of coordinated policies that eliminate differences between various sector-specific policies and provide feedback to city leaders in order to work more productively with each other as well as with citizens and businesses. The *Smart Economy* thematic area is focused on sustainable economic growth. It takes into account the innovation and entrepreneurship spirit of the city. The labour market and the companies' lifecycle demonstrate the dynamics of the economy.

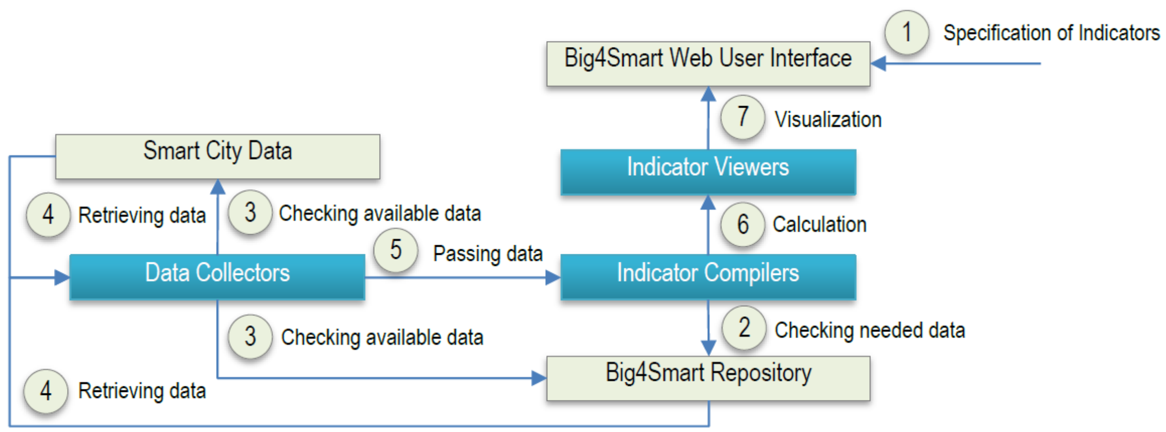

Figure 2: Calculation of indicators.

The international embeddedness is also analysed to obtain vision about the recognition of the city beyond the boundaries of the country. The *Smart Living* thematic area is directly related to the citizens' quality of life. Its dimensions show whether the cities are comfortable places to live focusing on aspects such as education, healthcare, housing, safety, etc. The cities are more than a combination of infrastructure and buildings assets. They are living ecosystem at the centre of which the *People* are. The smart cities need their residents to participate in the smart initiatives in order to be successfully implemented. The citizens need to adapt to new solutions, showing creativity and providing value to their community regardless of their diversity. Knowledge, professional qualification and skills form the main tool to improve the city performance. The *Smart Mobility* thematic area is related to delivery of efficient, safe, clean and reliable transport network for people, data and goods. The reduction of traffic accidents, environmental impact and demands on time and energy directly affect the mobility quality. The assessment of city mobility provides a valuable feedback for reshaping mobility patterns and planning mechanisms.

The thematic areas are further divided in several categories, shown in Fig. 3.

- *Smart Nature* – Water, Pollution, Waste, Energy, Land and Green environment.

The indicators related to water and energy are considered from two points of view – supply and consumption, and efficiency usage and management. The indicators assessing the pollution are divided in two groups regards to target of assessment: air pollution and noise pollution. The indicators of waste evaluate both solid waste and wastewater. The indicators assessing the land usage and status cover the change of land use, land degradation, land desertification, arable and permanent crop land, fertilizer use efficiency, use of agricultural pesticides and area under organic farming. The indicators of green environment asses the ambitiousness and comprehensiveness of strategies to improve and monitor environmental performance, the management of environmental issues and commitment to achieving international environmental standards.

- *Smart Governance* – Transparent governance, Participation in decision-making, Public and social services, Sustainable and smart city strategies and Governance effectiveness.

The transparency of governance can be assessed regarding the satisfaction with transparency of bureaucracy, fight against corruption and availability of open government data. The electronic public services answer better to citizens' needs and enable participation in decision-making and governance transparency. The participation of citizens in governance decision-making process provide inclusive and participatory growth of cities. The certification of the environmental management systems by international certification standards is a common practice at local level that indicates availability of sustainable and smart city strategies. The e-procurement transactions, development of monitoring systems and public-private partnerships facilitate governance effectiveness.

- *Smart Economy* – Employment, Economic growth, Innovative spirit, Entrepreneurship and International embeddedness.

The employment can be assessed through a wide range of indicators such as total unemployment rate, youth unemployment rate, female employment, etc. The economic growth has variety dimensions such as total investments, grants, total annual costs, payback and return on investment, gross domestic product, etc. The innovation spirit of the city is evaluated by SCIs such as Research and Development (R&D) expenditure in percentage of GDP, employment rate in knowledge-intensive sectors and number of patent applications per inhabitant.

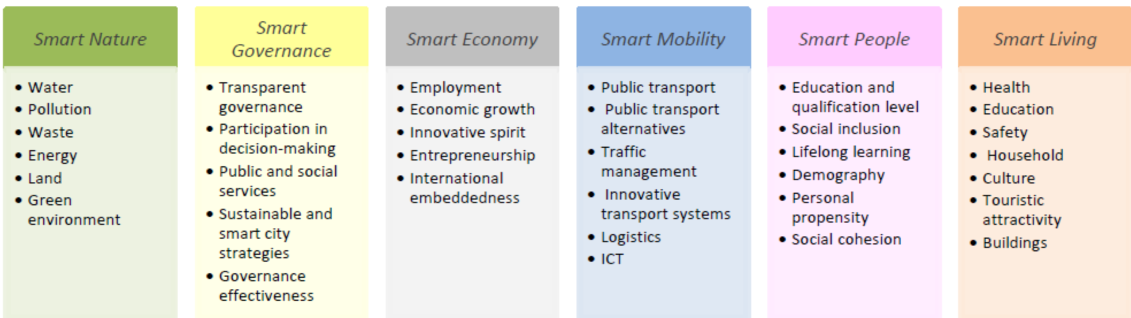

Figure 3: Classification schema of indicators.

The self-employment rate and new businesses registered are sample indicators for assessment of the entrepreneurship in city development. The business and commerce networks, and online presence of businesses are another dimension of international embeddedness.

- *Smart Mobility* – Public transport, Public transport alternatives, Traffic management, Innovative transport systems, Logistics and ICT.

The indicators of public transport alternatives assess the usage of bicycles, private cars and walking as means of moving. The indicators of innovative transport systems are focused on development of sustainable, safe and clean transport system. The indicators of ICT are divided in three groups, namely Connectivity, Informational awareness and Digitalization.

- *Smart People* – Education and qualification level, Social inclusion, Lifelong learning, Demography, Personal propensity and Social cohesion.

The education and qualification of citizens are an important social and territorial competitiveness factor. The indicators of social inclusion assess the civic engagement in decision-making and full and equal participation of people in economic, social, cultural and political institutions. The affinity to life-long learning is essential to sustainable development of the cities since the scale and quality of human capital are directly related to the creation and dissemination of new knowledge. The indicators of personal propensity are related to individual characteristics such as creativity, open-mindedness, flexibility, cosmopolitanism, etc. leading to personal success and innovation. The social cohesion is a characteristic of society which depends on the accumulated social capital and could be assessed for example using indicators of gender discrimination and the inequalities, poverty and Gini coefficient.

- *Smart Living* – Health, Education, Safety, Household, Culture, Touristic attractivity and Buildings.

The accessibility to basic healthcare and encouragement of a healthy lifestyle are core indicators of healthcare. Undoubtedly, the shares of students completing the primary, secondary and higher education are critical indicators of education system. The indicators of household give evidence about the breakdown of housing sector by property type (owner occupied or rental, single occupant, couples, family or multifamily occupant, etc.) and measure the housing quality as a degree to which inhabitants suffer from poor housing conditions. The share of natural disaster related deaths and number of citizens living in disaster prone areas as well as the share of population affected by crime or traffic accidents are critical indicators of safety. The tourism intensity is a distinctive indicator of city appealing since the tourists also interact with city services and affect the city profile. The sustainability in new buildings and in building renovation, the policies and systems of energy consumption and sustainability of buildings are sample indicators of buildings.

5 CONCLUSIONS

Due to urbanization the cities meet a lot of challenges affecting both their economic performance and well-being. Some of them, like higher prices of services and goods might be directly measured, and others, such as pollution, traffic congestion and limited parking spaces, are difficult to quantify in term of cost. This paper proposes an architecture of technological platform of indicators to monitor and assess the performance and sustainability of smart cities. It presents the building components of the architecture and the adopted classification schema of indicators covering six thematic areas, namely Smart Nature, Smart Living, Smart Mobility, Smart Governance, Smart People and Smart Economy.

The validation of the platform will be performed using real data collected from Bulgarian cities. Sofia is considered as a pilot city for conducting validation experiment. The ambitions of Sofia to become a smart city are laid down to the Sustainable Energy Action Plan 2012-2020 (SOFENA, 2012). Sofia Municipality is a partner of European project Smarter Together. Its objective is to replicate the key findings from lighthouse cities Vienna, Munich and Lion in targeted areas, implementing them in different urban and institutional environments. A current project of Sofia Municipality is “Integrated metropolitan urban transport – Phase II” funded by Operational Programme "Regions in growth" 2014-2020. The 2020 vision of Sofia is to become “The green and smart capital of Bulgaria – a model for sustainable development”. The foregoing as well as the support of the project by the Sofia Development Association, motivates the choice of Sofia as a pilot city for validation of the proposed solution.

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