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FUTURE CITY: A PILOT PROJECT OF GATE CENTER OF EXCELLENCE*

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ABSTRACT. Citizens and cities' government meet several challenges due to urbanization. The well-being of the citizens depends on the cities' government, while the citizens apply information and communication technologies (ICTs) to improve society's quality of life. The cities' government and citizens need to work together to provide a "smart" living environment. The modern ICTs, including Big Data, IoT and Cloud, enable cities to become smart. They are a successful factor for development of smart solutions that provide information about what is happening in the city, timely response to citizen needs and better control of operations needed to increase the quality of life.

In such a context, this paper presents a pilot project in the area of smart and sustainable cities. The pilot project is planned to be implemented as a part of research and development activities of the

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future BiG DAta for SmarT SociEty (GATE) Center of Excellence that will be established as a joint initiative between Sofia University, Bulgaria and Chalmers University of Technology, Sweden. The concept of the pilot project is described, including its main objectives and reference architecture. The possible application scenarios, covering different city dimensions, are discussed.

1. Introduction. Cities perform a variety of tasks that are undertaken by different departments and have specific dimensions, as follows: Social services; Transport, including roads, public transport, parking areas, etc.; Education; Healthcare; Housing; Waste management; Public spaces; Culture and leisure; Demographics, such as births and deaths. Each task can be handled at multiple levels with budget and decision making divided between them. At the same time, the city's departments tend to be siloed, having expertise in their own field, but rarely outside of them. It is difficult to solve problems that need expertise from several departments simultaneously and to decide on the responsibilities and budget of each one. Furthermore, there is often an overlap between the departments. For example, children need to travel to their schools, but the link between transport and education departments is often missing. The departments in the same area of operation also may lack connection. For instance, the traffic and public transport authorities might rarely interact. Since cities do not exist in isolation and they are influenced by government policies, people and businesses outside their boundaries, the decision-making process becomes more complex.

An increasing number of smart city initiatives exist all over the world aiming to deliver better planned, more connected and more livable cities. Amsterdam in the Netherlands, Barcelona in Spain and Stockholm in Sweden are remarkable examples of implementation of smart city vision. A significant number of events such as conferences and exhibitions dedicated to smart cities are held every year. In 2011, the global event Smart City Expo World Congress was launched in Barcelona. Annual country-specific events, such as the Smart Cities Week in Washington DC, the Britain's Smart Cities conference and the Via Expo Smart Cities Exhibitions and Conference for

South-East Europe coming up in Sofia, Bulgaria, are also organized. *All current activities are mainly focused on improving the current living conditions in cities and are often related to specific city dimensions* such as e-ticketing, smart street lights, pollution reduction, etc. *But what is beyond the smart city is the information-rich city presented with intelligent models that support the planning, design and analysis of all city dimensions.* Following this direction, the "BiG DAta for SmarT SociEty" (GATE) project [1] defines its concept, research and application activities in the field of smart and sustainable cities. The GATE project vision is oriented towards the establishment and long-term sustainability of a Big Data Centre of Excellence (CoE) that will produce advanced science by seamlessly integrating connected fields and associating complementary skills. The following have been outlined by RIS3 [2] and selected by the project team as sectors that are especially promising with regard to Big Data Value and form *GATE Data Driven Innovation Pillars.*

- *Data Driven Government (Public Services based on Open Data):* The collection and exploitation of real-time data from people, public authorities, public registries, etc. will be the basis for the creation of new ICT services and networks. The advanced value-added Open Data services will facilitate access, navigation, searching and reuse of data for citizens and will increase efficiency in public administrations processes.
- *Data Driven Industry (Manufacturing and Production):* With the advent of smart factories with intelligent and networked sensor-equipped machinery (Internet of Things), the production sectors in 2020 will be one of the major producers of (real-time) data. The application of Big Data into this sector will bring efficiency gains, predictive maintenance and entirely new business models.
- *Data Driven Society (Smart and Sustainable Cities):* City mobility, transport and logistics are among the most complex Big Data settings. In addition to sensor data from infrastructure, vast amounts of mobility and social data are generated by smart phones, C2x technology

(communication among and between vehicles), and end-users with location-based services and maps. Big Data will open up opportunities for innovative ways of monitoring, controlling and managing more effectively the whole city ecosystem.

- *Data Driven Science:* The scientific community is rapidly moving forward with the adoption of the Big Data technology stack. Big Data is steadily merging with traditional High-Performance Computing architectures. Today significant amounts of data can be collected and analyzed in the pursuit of unparalleled understanding of nature and the universe.

The goal of the paper is to present a pilot project in the field of smart and sustainable cities that will be implemented by the future CoE. The overall aim of the pilot project, called *GATE Future City*, is to provide city stakeholders with ability to make better decisions by relying on data from each other instead of their own data. As a result, a *City as an Intelligent platform* approach will be elaborated to *address the city challenges through using Big Data and IoT technologies.*

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 concept of GATE Future City is described in Section 3. Section 4 is devoted on application scenarios of GATE Future City. Conclusions and directions for future work are outlined in Section 5.

2. State-of-the-Art. Several frameworks related to performance evaluation of smart cities are developed within European Framework programs.

2.1. State-of-the art at European level. There are many undergoing FP7 and Horizon 2020 projects and research initiatives related both to Big Data and Smart Cities. Table 1 lists several that are very relevant to Big4Smart research.

Table 1. Relevant FP7 and Horizon 2020 projects and research initiatives

Ref.	Description	Relation to Big4Smart research
5	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, focusing on the intersection of Energy, ICT and Transport.	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.
6	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.	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.
7	SMARTIE develops a distributed framework to share large volumes of heterogeneous data in smart-city applications.	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 analyzed.
8	EU CIP Open Cities project aims to validate Open Innovation methodologies to the Public Sector Future Internet Services for Smart Cities. It uses platforms in Crowd-sourcing, Open Data, Fiber to the Home and Open Sensor Networks in seven major European cities.	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.

9	FIWARE is a 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.	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.
10	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.	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 of the Bulgarian level. In recent years Big Data and Smart Cities challenges have become a research topic for Bulgarian academia, public administration and industry. Research endeavors are not isolated at a national level but are taken in collaboration with leading EU and world research teams and organizations. Even though the obtained results are promising, they still provide only limited solutions related to specific aspects and do not implement 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. Relevant projects and research initiatives at national level

Ref.	**Description**	**Relation to Big4Smart research**
11	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	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.
12	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	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.
13	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	Big4Smart investigates the developed by Sharing Cities technologies to manage data from a wide range of sources, including sensors, and will built upon them.
14	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	Big4Smart investigates the mechanisms for data analysis for integrated planning of measures to reduce energy demand and maximize renewable energy supply.

15	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	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.
16	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 Ontotex	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. GATE Future City Concept. While the current smart city projects aim to apply the technologies to improve a particular aspect of city living, the GATE Future City as a Platform will *enrich the technologies with policy, politics, governance, etc. in order to make the smart city happen.*

3.1. GATE Future City Objectives. The ***short-term goal of GATE Future City*** is to implement several proof-of-concept use cases to raise the awareness of the community in four directions:

- Environment: Improvement of city environment through better urban planning.
- Traffic efficiency: Reduction of traffic congestion.
- Traffic safety: Providing better safety for city residents.
- Accessibility: Maintain operative public transport.

The cooperation among the city stakeholders and communication between city department is a key factor for cities to become “smart”. For instance, the connected vehicle environment includes three major approaches to communication, such as vehicle-to-vehicle (V2V), vehicle-to-infrastructure (V2I) and vehicle-to-pedestrian (V2P). In V2V communication one vehicle could send a message for availability of traffic accident to another one behind. The V2P communication covers all city road users including pedestrians, children in strollers, people using wheelchairs, cyclists, etc. The V2I communication involves vehicles and infrastructure in terms of systems and networks that are maintained by city departments. This kind of communication could be implemented between vehicles and traffic lights or vehicles and speed limiters.

Whatever communication is taking place, all parties need to collaborate to achieve a benefit. But why should the driver pay for an in-vehicle system if the beneficiary is the city, and why should the city pay for a system if the beneficiaries are the drivers? This brings a challenge to the GATE Future City to find mutually beneficial solutions. Therefore the short-term objective is to establish a strong collaboration between stakeholders.

The GATE aims to create a City as an Intelligent platform allowing designing, building and operating cities starting from data modeling of buildings and infrastructure in cities and spanning higher level of geographic entities such as entire countries—and why not "planet data modelling"?

The ***long-term goal of GATE Future City*** can be summarized as follows:

- Building Cities as Data Innovation Hubs in which the citizens, public bodies and private sector collaborate actively on Big Data potential. Collaboration will be on either a project-specific or data fellowship basis (to aid the transfer of skills).
- Delivering technology-enhanced data services that enable secure sharing of sensitive and new forms of city data as well as managing the flow of real-time city data collected by sensors, mobile devices, etc.
- Delivering harmonized datasets that are subject to greatest demand from city stakeholders and using them to deliver different forms of value.

- Providing the worth of data science approaches, establishing a city data analytics and application research at the heart of city operations and activities toward innovations.

3.2. GATE Future City Reference Architecture. The GATE Future City aims to develop an extensible, proof-of-concept platform that hosts, maintains and delivers a wide range of services to citizens, government and businesses. The objective of the platform is to improve the city sustainability and performance by supporting innovations in companies as well as speed-up the efficiency of city administration. Aggregation of data from different data sources allows new value-added services to be offered as software components of smart city applications. The reference architecture of GATE Future City is shown in Fig. 1.

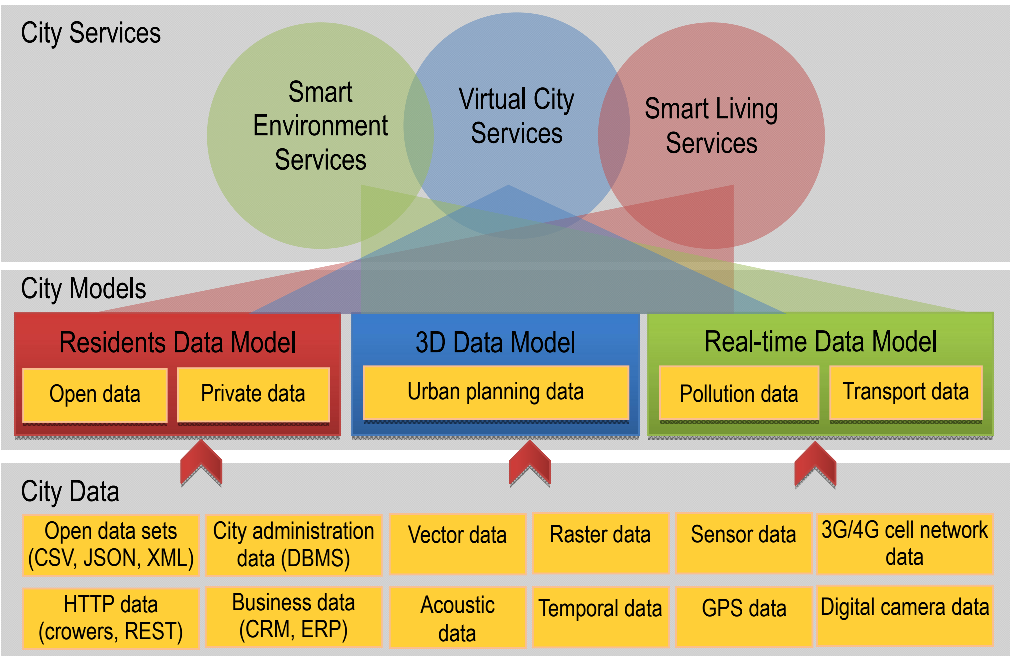


Fig. 1. GATE Future City Reference Architecture

The ***Data Models*** are intelligent city models that contain detailed information about their entities and relationships between them. They can be used by city planners and urban designers to plan out a city more effectively and efficiently. The intelligent city models enable simulations of a variety of city aspects such energy usage, traffic, congestion, natural disasters, etc.

Smart Living Services allows creating high-interactive applications that facilitate the life of citizens. For example, they will help people to search for properties based on personal requirements such as price, location, proximity to public transport, hospitals, schools and other facilities.

Virtual City Services provides tools for exploration of a city 3D model. They demonstrate how a 3D games engine could be applied for implementation of 3D visualization functionality in a client browser. These services help city authorities optimize urban the environment and improve the effectiveness of urban planning. For example, the 3D city model could be used to optimize and/or extend the city's power grid in response to the rising number of charging stations for electrical vehicles.

Smart Environment Services help both citizens and city authorities to understand the city's problems and hence to take actions towards their solving. For example, monitoring of school zone conditions, including current speed limits, detection of vehicles in or approaching the zone and sending a reminder of the current speed limit could be performed. These services are the most complex component of the GATE smart city platform from the point of view of data acquisition and data processing. They should allow data to be extracted from supported data repositories and presented on dashboards. In addition, real-time data processing and visualization should be supported.

The implementation of the GATE Future City concept requires the following aspects to be considered:

- what data is exchanged between city and stakeholders, including public authorities, citizens and businesses;
- how data is exchanged regarding the communication network (cellular networks, Wi-Fi, etc.);
- how data is presented to city stakeholders after processing and analysis;
- how data will be stored once it has been collected and how it will be assessed by third-party applications;
- how data will be used for automated control.

Thus, a set of interfaces need to be supported at five main levels: messaging, communication, application, visualization and control.

The GATE Future City will support the following output methods:

- Aggregated and linked datasets—datasets ready for processing built on top of raw data;
- APIs—APIs, ready for integration, for developing smart city applications;
- 2D visualization—dashboards for real-time presentation of data;
- 3D visualization—virtual reality in short-term and augmented reality (an overlay of content on the real world, but that content is not anchored to or part of it) and mixed reality (enabling synthetic content and real-world content to react to each other in real time) in the long term.

4. GATE Future City applications. This section presents the possible application of GATE Future City. Sofia is indicated as a pilot city for conducting the validation experiment during the project. The ambitions of Sofia to become a smart city are laid down to the Sustainable Energy Action Plan 2012-2020 [3]. Sofia Municipality is a partner of the European project SMARTER TOGETHER [11]. Its objective is to replicate the key findings from the lighthouse cities Vienna, Munich and Lyon 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 the 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 [4] motivates the choice of Sofia as a pilot city for validation of the GATE Future City.

4.1. Smart demographics. Analysis of the movement of students and skilled workers and predicting areas which are prone to demographic booms and depopulation is important for the development of business clusters. By doing so, real estate prices can be forecasted, together with the potential related businesses which will be required in these areas. Clear linking patterns exist between different types of buildings and infrastructure. As an example, all newly populated neighborhoods initially need bus stops, grocery shops and schools in order to provide the minimum life standard of the citizens. Together with cameras and cell phone signals, detailed density maps can be created in order to facilitate smart city planning and spacing optimization (see Fig. 2).

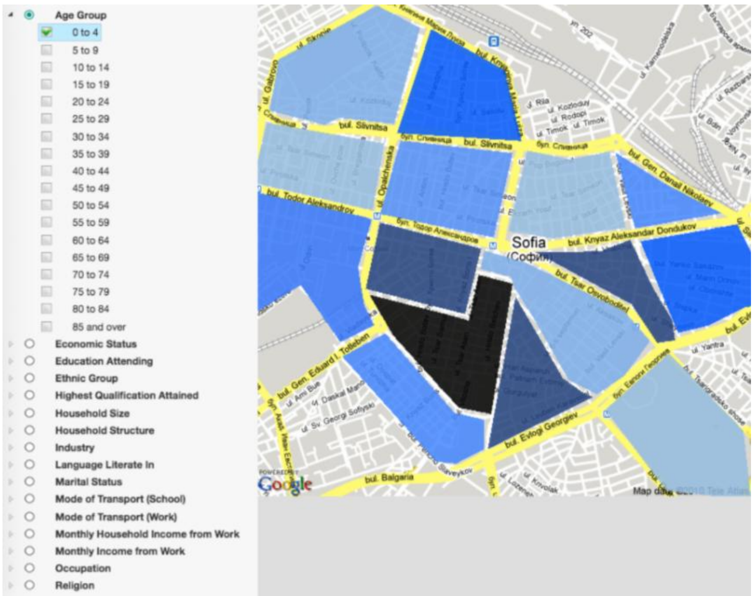


Fig. 2. Sociodemographic analysis of city regions and buildings.
Source: Open Street Map [17]

The benefits from the application of GATE Future City to smart demographics can be summarized as follows:

- Discovery of hidden socioeconomic processes which can affect businesses.
- Optimization of data visualization for policy makers, in order to ease the process of regional decision making.
- Hidden microeconomic factors which foster or prevent the development of certain areas can be revealed upon analysis of demographic data with economic data from other systems.

4.2. Smart city planning. According to the cluster strategy, similar businesses are always located near each other naturally due to the close location of the customers, hired workforce or other jointly used resources. Likewise, new neighborhoods in the city are also formed by citizens with similar demographic characteristics. It is true that city architects are the final decision makers on what is to be built where, however their decisions are often made mostly on the basis of intuition and not by considering multi-dimensionally related factors. Business owners choose their locations of operation primarily because of the real estate prices they are offered, overlooking insights of demographic and business movements. The government can easily detect areas with promising conditions for specific business activities and send notifications directly to companies which are looking to expand their offices (see Fig. 3).

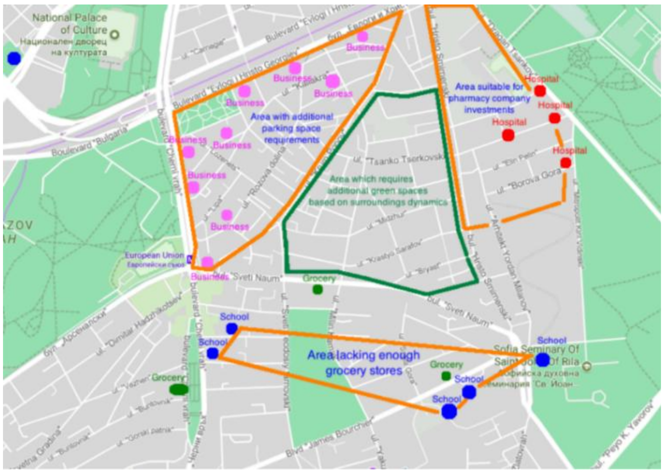


Fig. 3. Smart city planning automatic indicators. Source: Open Street Map [17]

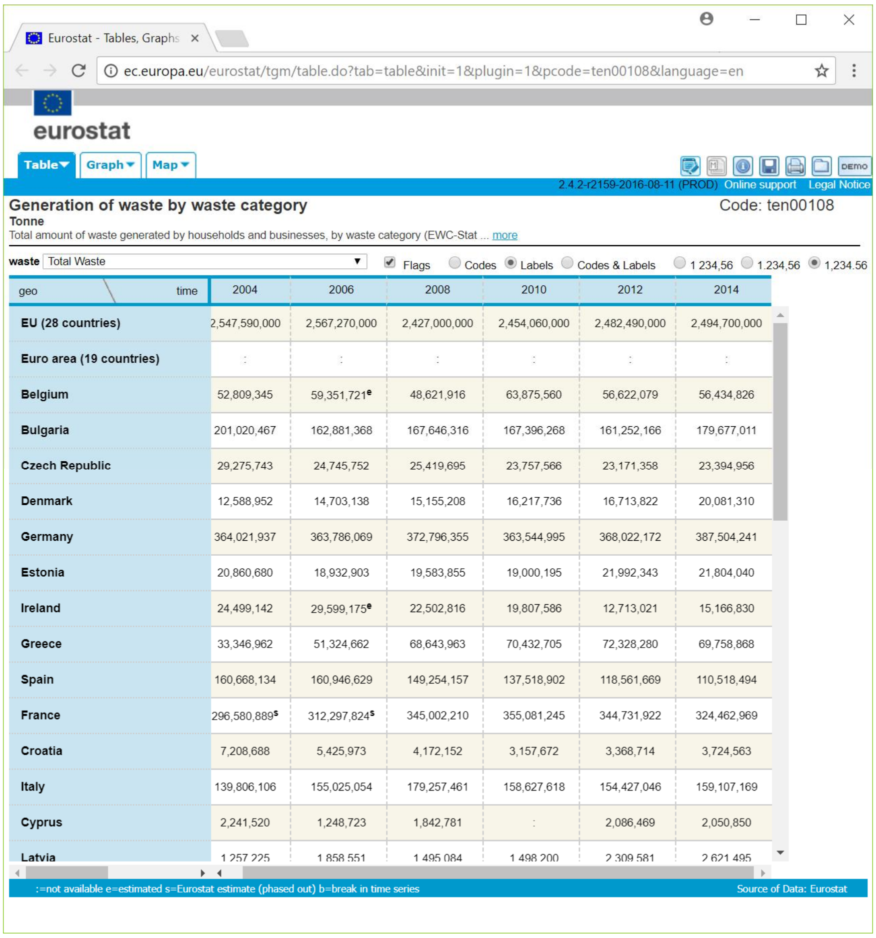
The application could be integrated with the smart population monitoring platform and estimate estate prices and provide suggestions to business owners for areas with less competition and better estate prices. Algorithms can also analyze consumption patterns, tax patterns, entrepreneurship indicators, education patterns, medical records and other data in the region and provide the government with data on how to allocate funding to the most promising areas for building schools, hospitals and offices or detect areas with a need of developing additional businesses or market enterprise. The possible benefits from the application could be summarized as better data-driven city infrastructure planning as well as assistance of private business owners in targeting optimal locations with potential customers.

4.3. Waste management. In 2014 Bulgaria had 179 677 thousand tons of household waste, as shown in Fig. 4, while also being the member country with highest mineral waste per capita within the European Union. The statistics identify the waste management in Bulgaria as a problem which has to be addressed. Currently only some areas in some major cities in Bulgaria have containers for waste sorting, and those are often overlooked by citizens. Waste collection trucks patrol and collect the containers on repetitive schedules, sometimes picking up almost empty boxes. In the rest of the cases the containers become overloaded, with citizens being forced to put their waste simply on the ground near the container, spreading bacteria which are picked by the wind or passing nearby people, pets and vehicles.

A pneumatic system *allows automatic sorting of waste by its material type* while being transported via air or gas pressure. Sensors can detect and identify recoverable materials, transporting them to recycling centers and gathering data about the nature of the materials.

Another smart application is the adoption of *smart bins* equipped with sensors which report when their volume is about to be filled. Data is analyzed against existing consumption patterns to provide an estimate of the day and time for the waste to be collected. Additionally, smart bins are able to move intelligently between neighborhood streets when the machine learning algorithms predict underuse in the current location with alerts of overloading in the nearby neighborhoods. Combined with self-driving trucks, they can get picked up automatically, thus saving labor, fuel and time. The containers can also warn nearby cats or dogs which try to dive in them. The benefit of smart bins is that they can self-adapt to changing demographic and consumption habits dynamically, unlike the pneumatic system.

After the waste is disposed using sensors, it is fine-sorted intelligently. The content of the waste is analyzed in order to determine whether it can be used for *automatic recycling*. The waste which cannot be recycled is burned, and the energy released during the process is used for generating heat and electricity. Biogas is created from the burned organic wastes. The final ashes of the solids' waste which has been burnt can be used as construction material for roads or buildings (upcycling). Finally, a pattern analysis can be performed on the waste emitted by each city region and citizen group, providing reports for the ecological balance and carbon emissions.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EU (28 countries)	2,547,590,000	2,567,270,000	2,427,000,000	2,454,060,000	2,482,490,000	2,494,700,000
Euro area (19 countries)	:	:	:	:	:	:
Belgium	52,809,345	59,351,721e	48,621,916	63,875,560	56,622,079	56,434,826
Bulgaria	201,020,467	162,881,368	167,646,316	167,396,268	161,252,166	179,677,011
Czech Republic	29,275,743	24,745,752	25,419,695	23,757,566	23,171,358	23,394,956
Denmark	12,588,952	14,703,138	15,155,208	16,217,736	16,713,822	20,081,310
Germany	364,021,937	363,786,069	372,796,355	363,544,995	368,022,172	387,504,241
Estonia	20,860,680	18,932,903	19,583,855	19,000,195	21,992,343	21,804,040
Ireland	24,499,142	29,599,175e	22,502,816	19,807,586	12,713,021	15,166,830
Greece	33,346,962	51,324,662	68,643,963	70,432,705	72,328,280	69,758,868
Spain	160,668,134	160,946,629	149,254,157	137,518,902	118,561,669	110,518,494
France	296,580,889s	312,297,824s	345,002,210	355,081,245	344,731,922	324,462,969
Croatia	7,208,688	5,425,973	4,172,152	3,157,672	3,368,714	3,724,563
Italy	139,806,106	155,025,054	179,257,461	158,627,618	154,427,046	159,107,169
Cyprus	2,241,520	1,248,723	1,842,781	:	2,086,469	2,050,850
Latvia	1,257,225	1,858,551	1,495,084	1,498,200	2,309,581	2,621,495

:=not available e=estimated s=Eurostat estimate (phased out) b=break in time series Source of Data: Eurostat

Fig. 4. Generation of waste by waste category. Source: Eurostat [18]

The benefits from the application of GATE Future City to waste management could be summarized as follows:

- Reduce the cost and time needed for transporting and managing waste.

- Prevent spread of diseases near waste containers to roaming pets or passers-by.
- Full analysis of the lifecycle of materials and products. Detecting inefficiencies in product sale, consumption and disposal points can be analyzed and reported. In combination with big data from demographics and businesses, sophisticated consumption models can be created based on where the product was purchased and disposed, revealing consumer behaviors and providing feedback data to private businesses in the region.

4.4. Smart traffic. Transportation contains many interesting situations in which big data can be used for analysis and detection of patterns, which point out areas of optimization and cost reduction. One of the major issues in cities is parking. Parking habits can be easily analyzed via movement sensors placed in parking lots, which detect the availability of parking spots. Together with sociodemographic data (such as sleep patterns, work hours of nearby businesses and news from important events) smart notifications for all parking spots can be predicted, together with recommendations of the nearest available parking space.

Road sensors can also be used to track road conditions and create notifications to the local municipalities when a certain part of a road needs a patching, sending automatic reports to drivers about the road quality and possible safe alternative routes, together with locations of maintenance works.

Public transport vehicles can also be equipped with tracking sensors, measuring the quality of the roads (with statistics like road bumpiness or crowdedness). Cars owned by private individuals can be equipped with safety sensors, which communicate with smart road sensors and prevent exceeding the speed limit near sensitive areas (such as schools, crowded streets or sections with lower quality roads and concentration of incidents), with these spots being generated intelligently on the basis of the patterns continuously learned from data.

By merging crowdsourced requests and using anonymized public transport data, the platform is able to identify problematic areas and formulate solutions for avoidance of crowdedness, reduced wait times for transportation services and route suggestions (see Fig. 5).

Fig. 5. Smart City Parking and Traffic Prediction. Source: Google Earth [19]

Finally, sensors can be used for collecting smart vignette and parking taxes. In the European Union 22 countries are charging flat vignette fees for the usage of highways. The fact that the fees are flat entails that currently some citizens are charged more and others less, irrespective of their real use of the road system. As the price of a yearly vignette is close to the price estimate of a hardware device which is able to communicate intelligently with road sensors and determine the type of the road, it is possible to charge the citizens only for the distance travelled on roads requiring a vignette fee.

The benefits from the application of GATE Future City to smart traffic could be summarized as follows:

- prediction of dangerous road sections (such as schools, major crowding areas and etc.);
- automatic speed reduction near dangerous spots;
- automatic parking space prediction and notifications;
- accurate estimations about roads which are going to require repair, together with cost estimation;
- reduction of traffic jams, incidents, noise levels and carbon emissions;
- crowd and traffic optimization, especially during rush hours or in central areas;

- recommendations for road network optimizations based on traffic patterns;
- saving time and cost of transportation;
- more energy-efficient transport solutions for urban environments;
- tools that can give input into urban planning decisions.

4.5. Smart municipality. It is difficult for public administration personnel to balance between the budget and the perceived most important tasks which need to be addressed in the city. A possible solution to this is a platform which allows citizens to report issues which need attention by the public administration with their cell phones. As an example, citizens can submit photos of areas which need repair or point their cellphone to a smart device with sensors (like smart bins) and report its data and location with one touch. Every citizen can preview the reports and upvote an item once. The items with most upvotes are brought automatically to the attention of the municipality for solving. When an item is fixed, or a law is passed regarding its use, the citizens receive a notification message.

The benefits from the application of GATE Future City to smart municipality could be summarized as follows:

- identification of locations with critical infrastructure problems (road holes, lack of public transport, etc.);
- public administration will inform better citizens about the progress of the specific issues in which the individual citizen is interested;
- more direct and truly democratic management of public affairs.

4.6. Environment quality. The *emissions* from transport are the main contributor to air pollution. The Eurostat statistics show that the index of transport emissions in Bulgaria was 94.6 in 2015. This places Bulgarian in the top five countries in Europe with the highest air pollution form transport emissions.

The air of Sofia depends on climate and micro-climate conditions, the quantity and type of the emissions and the location of emissions' sources. The closed nature of the Sofia valley is a prerequisite for the retention of air masses, frequent occurrence of temperature inversions and fog occurrence. The natural dispersion of emissions is poor, leading to their remaining in the air, especially in the following meteorological conditions:

- quiet weather, accompanied by radiation temperature inversions, where the level of pollution in the whole city is increased;
- sustainable wind from the main sources of pollution.

At the same time, 30% of the Bulgarian industry is situated in the Sofia city region. A significant part of the polluters is located in residential areas or close to them. The lowest parts of Sofia city are characterized with the worst micro-climate conditions. The main industrial sources of emissions are thermal power plants, metallurgy and glass factories. Energetics is a source of nitrogen oxides, carbon oxides, hydrocarbons, sulfur dioxide, soot and dust. The automotive transport is another source of emissions. The major problem related to air pollution is the high concentration of fine dust particles. The analysis by Sofia municipality shows that the norm of fine dust particles is exceeded 35 times per year at all but one monitoring stations. The main anthropogenic source of sulfur dioxide is the burning of natural fuels, as well as metallurgy and the chemical industry. The nitrogen dioxide is produced during combustion processes. The monitoring stations, located at the urbanized part of Sofia city, show that the high levels of nitrogen dioxide in the air are due to the transport sector (80–90%), followed by the industry sector (10–20%). The Sofia municipality has developed and accepted a program for reduction of emissions and reaching the standard norms of fine dust particles and nitrogen dioxide as well as for quality control of the air.

The main sources of *noise* in Sofia city is likewise the transport. The major noise background is created by the cars, trucks and vehicles of the public transport. The highest levels of noise are due to the public transport, especially older busses. The tram and trolley transport, intersections of city railroads as well as planes landing at and departing from Sofia airport are another considerable source of noise.

The *climate changes* are an expected result of the air pollution. By the end of the century, the average annual temperatures in Sofia city are expected to change by more than 4°C. The average annual rainfall is expected to change up to 20%. According to the forecasts, the number of nights with air temperature above 20°C (tropical nights) will increase. Thus, Bulgaria is among the riskiest parts of Europe. In addition, the number of snowy days is expected to decrease. The reduction of snowy days for the Sofia region is expected to be between 20 and 40. According to the Climate Change Vulnerability Index (CCVI), calculated for the NUTS 2 regions of EU, Sofia city falls into group 4 of a total of 6 groups.

The benefits from the application of GATE Future City to environment quality could be summarized as follows:

- reduction of carbon emissions, fine dust particles;
- reduction of radiation from industry;
- better communication of air quality issues, including in the urban planning process.
- better modelling and prediction of air quality.

5. Conclusions. The cities are the dominant residence of the people, increasing the countries' production capacity, hosting the education and research organizations and fostering the creativity of human beings. At the same time, the cities are the largest consumers of energy, the major pollutants of the environment, a convenient place for criminals and anonymous living. This brings a lot of challenges to the cities' government, which needs to regulate all negative aspects that the cities' large society can cause. The GATE project addresses these challenges by focusing on them of its research and development activities towards implementation of the so-called GATE Future City.

The GATE Future City, presented in this paper, aims to develop an extensible, proof-of-concept platform that hosts, maintains and delivers a wide range of services to citizens, government and businesses through using Big Data and IoT technologies. The objective of the platform is to improve the city's sustainability and performance by supporting innovations in companies as well as speeding up the efficiency of the city administration.

Future work includes further exploration of Big Data research and applications in the field of smart and sustainable cities. The available data sources for this will be analyzed and a detailed plan for implementation of GATE Future City will be elaborated.

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