CitiSim – IoT platform for monitoring and management of the city

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Abstract

Current technologies have created new methods of monitoring and organization of the problems in our society, in particular, those arising from the cities. In order to become more connected with the environment and to find solutions to daily problems, such as traffic, pollution or energy consumption, several research, and development projects that focus on these issues were developed. The existence of an intelligent platform for the monitoring and control of the city could be of considerable benefit in the development of the ecosystem at the level of a city. Such a platform, that proposes the development of intelligent services at the level of the towns, is CitiSim. The purpose of the CitiSim platform is to allow users to take management decisions even in critical situations or emergency, on the basis of data provided by the sensors. The expected results shall include the creation of a 3D visualization tool for the monitoring and control of the city and the use of techniques for viewing enhanced publication and reality enhanced publication. For the implementation of the details at CitiSim platform architecture has been used as middleware ZeroC Ice. The chosen programming languages for the implementation of the prototype are Java, *JavaScript, and Python. The libcitisim library has been introduced into the system architecture to provide access to the lower level events of a smart city to simplify the development of new services. It will also be available the service for emergency cases simulation which will use special devices for 3D visualization and augmented reality. The devices used for visualization of 3D equipment are 3D glasses that allow you to view the models of buildings and escape routes. The development with 3D models will be done using Unity Engine that uses C# and Unity Script– a JavaScript-based language-as developing language.*

Keywords: *3D visualisation, augmented reality, smart environment administration.*

1. Introduction

Over the past years, with population growth, our society has faced new kinds of problems, which imply traffic congestions, air pollution, deteriorating infrastructures, difficulties in waste management, the decrease in non-renewable resources. In cities and, especially, megacities, the quality of life depends on some types of factors, such as traffic, citizens' safety, sustainability, local administration or energy consumption.

These complex challenges have triggered lots of cities around the world to find smarter ways to manage them, defining the new concept of "smart cities" and making significant advancements in this direction by using modern technology. A city can be called "smart" when investing in human capital, social, energy infrastructure, communications, transport, emergency services, etc. are designed to be sustainable in time and when it can ensure a high standard of living supported by a performant and involved administration.

Communication systems, in a smart urban space, must work perfectly so that they can analyze and decide at any time to solve all problems of any nature. Using low-power sensors, wi-fi networks, digital surveillance, automated data processing, and public service management systems are just a few examples of digitization and opportunities for smart cities. Among the parameters that will define a smart city in 2020, we mention: smart lighting equipment, intelligent surveillance, smart and automated buildings, smart and connected medical devices, biometry, eHealth, e-education, eGovernment, sensor networks for digital resource management, intelligent transport, mobility with redundant emissions (De ce orașe inteligente, 2018).

One of the approaches to the smart city requires an IoT (Internet of Things) platform that will be managing and enabling diverse technologies, systems, services and applications. This platform is a framework for integration, communications and an intelligent decision-making process (Smart City platforms - the Intelligent Core of Smart Cities, 2015). Such a platform is CitiSim whose aim is to design and implement a new generation platform for the Smart City ecosystem. CitiSim is a 3D visualization tool created for smart city control of the infrastructure and powerful monitoring. In order to develop a better understanding of the events in the city and to create a natural interaction, augmented virtuality and augmented reality will be considered as visualization techniques (CitiSim, 2018).

The paper is organized as follows: Section II provides an overview of Smart City management solutions available on the romanian market, Section III describes the architecture of the CitiSim platform, Section IV presents the common framework, and the final Section concludes the paper.

2. Related work

Cluj IT (Cluj IT, 2018) is a cluster that has created an ecosystem for developing services and software products by sharing knowledge and ideas with other organizations and businesses in the public or private environments. Cluj IT provides urban services in the following fields: public administration, traffic and mobility, public security, health and education, culture,and entertainment, tourism, utility infrastructure, energy, work and housing etc.

These services are provided and implemented by several IT organizations, that are actively involved in this process. The level of involvement of the organizations in the context of smart city consists in providing: access control systems, systems for managing public procurement processes, modeling systems and virtual space navigation, hybrid cloud solutions for video communications and online collaboration, infrastructure and smart traffic software, smart parking systems, solutions and systems for cultural and educational institutions, smart solutions for recreational activities and tourism development, virtual / augmented reality, intelligent brokerage platforms to supply the city with environmentally friendly products, Middleware platforms for intelligent WSN sensor networks, monitoring, control and energy management, smart power grids and city health.

The Intracom Telecom (Intracom Telecom, 2018) Smart City proposition integrates Smart Infrastructure, Data Transmission & Storage, and Applications & Services, that can help Smart City organizations such as municipalities, service providers, enterprises, etc., to better visualize the city of the future. Intracom provides a command and control platform for powerful IoT and Smart City services. It also supports new verticals in addition to smart lighting, such as sound, waste, traffic,and parking. The use case of Noise/Sound Smart app includes: Real-time information on City map, Security dispatch, Dashboards presenting the noise level, Automatic notifications sent to Authorities when noise limits reached or patterns identified (e.g. traffic accident), Sound to image correlation, Public Transportation plan improvement to reduce Traffic Noise in City Center and EU defined Noise Levels calculated. For traffic Monitoring Surveillance and they offer Traffic flow monitoring, Anonymous Traffic counting using Ultrasonic technology, Movement information by Doppler measurements, People counting using Bluetooth/Wi-Fi technology, Advanced security through Surveillance, Security on the fence. Smart Cities offer unique opportunities for monetization via: Dynamic pricing based on Smart service user/consumer behavior (e.g. for Waste Management), Direct and Indirect revenues generation (Smart parking, targeted advertising), Objects classification and decision making using machine learning techniques, Support of multiple Payment Models (Pre-paid & Post-paid), Flexible charging models (e.g. combination of subscription fees with Pay-per-Use charges) or Smart service demand (e.g. last parking space).

IndSoft (IndSoft, 2018) promotes the concept of smart city at a national level through ICT solutions. IndSoft serves a diversified client base, including start-up companies, small and midsize businesses, Fortune 500 companies, as well as State and Government agencies. Proprietary automated tools, experienced teams, and best practice processes are the foundation of IndSoft's core practice areas. The Smart City solutions involve: Smart Governance, Smart infrastructures, Public security, Smart mobility.

The Smart City projects that are implemented in the city of Brașov include smart lighting, smart public transportation system (e-ticketing), public security (video surveillance in the city and schools), integrated technical dispatch, geographic information system. SMART solutions includes: Sustainable development strategy, Integrated Urban Development Strategy, Sustainable Development Strategy 2030, Sustainable Urban Mobility Plan, Sustainable Energy Action Plan 2010-2020, Electronic e-Administration services (Public lighting network, Municipal networks, Cadastre, Green areas, parks, recreational zones, Public utility objectives, Urbanism plans, Public and residential parking, Public transport system) (Brașovul pe harta Smart Cities of Romania. De la viziune la realitate, 2018).

The goal of the Smart City project is to make the public life better, to promote technical innovation and to improve the efficiency of urban management. The project can be implemented by using ICTs such as high-speed mobile internet, big data, IoT cloud computing etc. ZTE Smart City 3 provides more innovations, such as Big Data Operations.

This version is people-oriented,and its goal is to achieve great collaboration by a great connection. The upgrades of the project include: Cloud Network Map Top Level Design, Big data cloud platform (UOC). Smart City 3.0 Prospect: Highly developed ICT infrastructure (Active perception, Perception Crowdfunding, Neural network, Self-learning Pre5G 400G, LoRa, NB-IoT), Standardized open big data (Data Standard, Quality, Privacy, Security Data API service portal), People-oriented application operation (Public participation & decision Crowdsourcing & crowdfunding Collaboration of government, enterprise & citizen). In order for the Smart City ecosystem to work properly, the whole society needs to engage in the project. For greater data value, the smart cities should be globally connected (http://wwwen.zte.com.cn/en/, 2018).

3. CitiSim proposed system architecture

The architecture proposed for CitiSim platform should be flexible in order to support different operating systems (Linux, Windows, Android, etc) and different programming environments (C++, Java, etc.).

The access of the CitiSim services from third parties to the Internet is done using REpresentational State Transfer (REST). The core service implementation of the internal middleware should be flexible enough to support security issues, scalability, flexibility, etc. The proposed architecture of CitiSim is presented in Fig. 1.

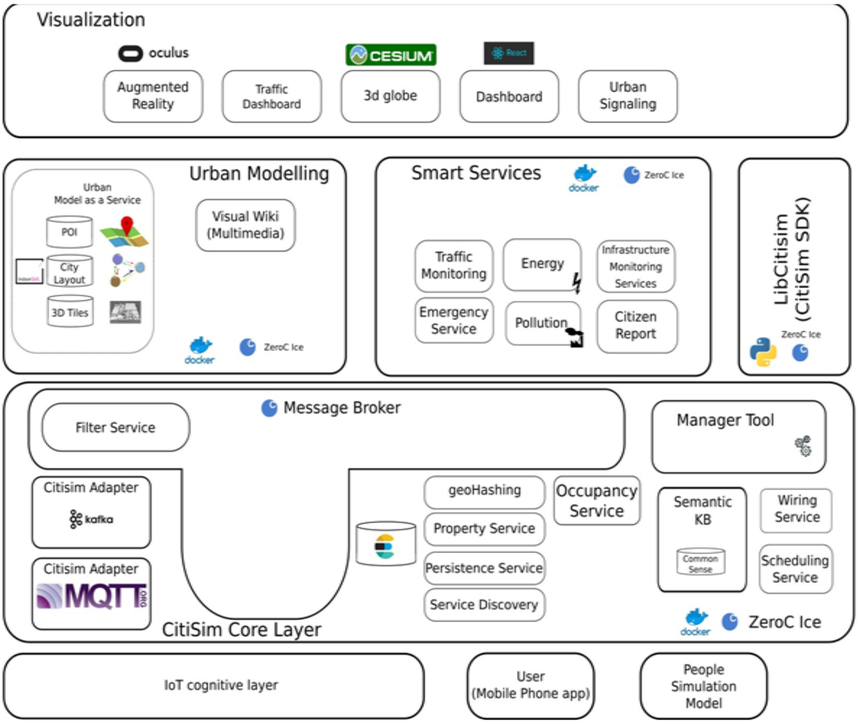

Figure 1. CitiSim conceptual architecture

IoT Layer: This is the layer where the information is collected from sensors/ actuators. Each sensor will register in the message broker through an interface as a publisher and will call the message broker in order to interface periodically with its values and the metadata about reading (e.g., Timestamp, quality of reading, Expiring time, etc.). The actuators will implement a simple interface to change the environment. For the simulation plane, the same method will be used for the simulation algorithms. A service from the upper layer doesn't distinguish among real and simulated data. Nevertheless, timing and critical aspects should be taken into consideration (Zhou, 2018).

The mobile user apps enable the users to access the information which CitiSim platform will provide. The component will be used to show information about the traffic.

Core Layer: This layer represents the CitiSim (CitiSim, 2018) platform itself. It is used if a city runs a single instance of the core layer in to support the rest of the services.

The main components of this layer are:

Message Broker: The main component of CitiSim system architecture is the message broker, used for the distribution of information (sensor information, raw data, events, etc.) among the smart services and core layers. Using this broker, each service has to subscribe to the specific topics and also has to publish the generated information. Topics are logical buses where information is published. They are using different interfaces which define the different types of messages. For example, several sensors are sending information from the IoT layer, which is related to true/false information and are sending the following interface: void notify (Metadata data, string source, bool value). All the services, which are interested in this type of information will need to implement the notify method for every service;

Filter Service: The filter service is defined to subscribe to specific topics in order to scale properly. This way, only the information which passes all the filters defined by their relevant services will be communicated. The filters are set up on the subscription phase;

Property Service: The property service is devoted to store semi-static/static properties of services/devices in an instance of CitiSim platform. For example, the manufacturer of specific actuators, the last revision of an extinctor, the position of a smoke sensor are examples of the information which can be accessed/stored through the property service. The information will be stored by the property services in a data store;

Persistent service: The persistent service is subscribed to all the topics from the message broker and stored in a data store. This service will compact and store information about the city;

Semantic KB: Semantic KB is a knowledge database which will store the following types of information:

(1) relations of concepts and vocabulary in a current city. The semantic information is common for any developed city. The services will use the vocabulary for its interfaces, metadata, etc.;

(2) rules regarding traffic and pedestrian;

(3) service description of the instances in this instance of CitiSim.

Scheduling service: The scheduling service will define the new desires expressed by a user or service and the complex behaviors to the deployed services. For example, the authorization to go inside of a building will be done by using several methods (personal identification number (PIN) code, facial recognition, radio-frequency identification (RFID) tag, etc.) according to the deployed infrastructure. This service can link to access the methods with the Access/Authorization service dynamically under an access request done by the user;

Semantic Service: The semantic service will manage the information at the semantic level and will integrate other domains along with CitiSim domain;

Manager Tool: The manager tool is used for monitoring the CitiSim platform (state of the devices/services);

Adapters: The adapters are modules which interconnect CitiSim domain (together with the semantic service) along with other domains (e.g. Sofia2 services, MQTT devices, etc.).

domains: (e.g. Sofia2 services, MQTT devices, etc.).

Urban modeling layer: The urban modeling layer will store structural information about the city. The main components of this layer are:

Visual Wiki: Visual Wiki includes information (including multimedia) about the city using different formats;

Urban model as a service: This component is a repository which stores different models with information about 3D building models, urban furniture, supplies model (energy grid layout, water grid layout, etc.), street layer. The three initial repositories will be a Point of Interest (CitiSim, 2018) repository with specific information about cultural buildings, monuments, etc. devoted to tourist applications. The main idea is to offer the information through an API to build visualizers which can access the information remotely and can also provide information updates by a push model (e.g. water leak and affected area, street cut by some unusual event, etc.).

Smart service layer: The smart service layer provides services related to the stakeholders of a Smart City. Firstly it takes the collected information from the core layer and then it uses the urban model layer to provide the services.

The services can be implemented and modeled according to different use cases. From the currently defined use cases, the smart services which will be performed are:

Pollution, Energy,and Infrastructure monitoring service: The monitoring service will provide information about a specific domain and will enable the control of the specific devices. In the case of energy, the monitoring service will enable/control/ operate specific devices which can turn on/off the energy infrastructure;

Cultural agenda: This service will introduce information about the cultural event from a central point. The central point will be the primary source of information for apps, visualizers, etc;

People monitoring: The key idea of this service is to estimate, from different sources of information (e.g. video analysis, sensors, access services, etc.), the occupancy of different areas at specific times. This service will store, with different accuracy, the number of people in particular areas;

Traffic monitoring: This service will gather information about the traffic conditions in the street layout;

Emergency service: The emergency service will follow a set of steps when is detected a specific emergency. For example, the emergency service will provide the evacuation paths according to the type of the emergency and the status of the infrastructure;

People Simulation model: The people simulation model will provide information regarding simulations of movements of virtual people. For example, this service can be used to observe and estimate the evacuation time of people in case of an emergency.

The set of services of the smart service layer is not closed, according to the evolution of the project, it could be possible to split services in more functional one or implement new services if needed.

Finally, the **virtualization layer** will provide to final users (companies, citizens, mayor, etc.) the information regarding different aspects of the data managed in the CitiSim instance.

4. CitiSim common framework

The objective of the CitiSim platform is to provide a service development and event processing environment, specifically tracking, analyzing and solving where applicable (e.g emergencies). To identify relevant events and to respond more quickly to citizens' needs, the complex event processing method is used, which analyzes data from multiple sources.

The figure below shows schematically the route traveled by sensor data collected from the bottom layer to the upper layer where these data are analyzed and where a decision is made in accordance with the occurrence.

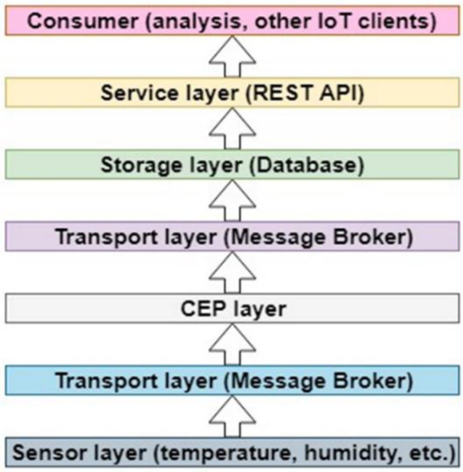

Figure 2. The flow of information from the sensor layer to the consumer layer

The server that stores event data sends alerts to WebSockets. A flow representation between the CitiSim components can be seen in Figure 3.

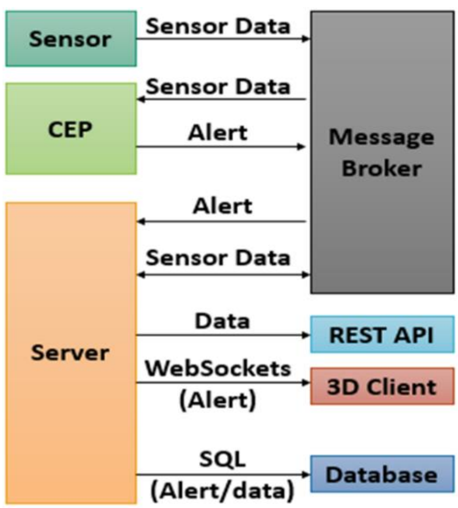

Figure 3. Data flow between components

The modules of the CitiSim platform and the technologies with which they were developed are depicted in the figure below.

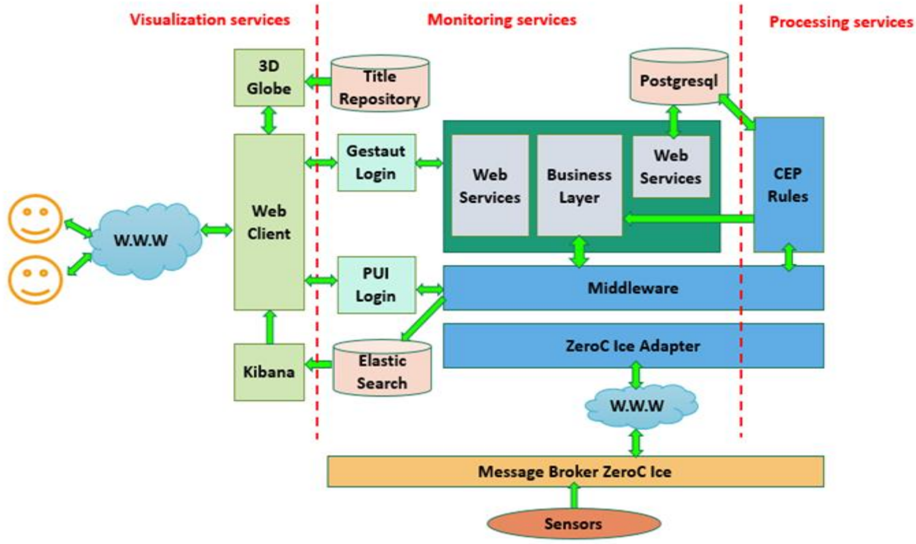

Figure 4. Modules of the CitiSim platform

Modules grouped by the technology used are:

- **Applications server (PUI Server) and Middleware**: developed in the Java programming language. JSON, CSV, XML, and also uses JavaEE, Spring,and PUI;
- **Complex Event Processing:** Developed with the WSO2 framework and Siddhi language;
- **General Database:** PostgreSQL and SQL;
- **Web clients:** Developed with PUI client technology in JavaScript;
- **Message Broker:** ZeroC Ice using RPC. Supports: C#, C++, JavaScript, Java or Python.

Middleware is an API that acts as a communication method to the application server or other clients. Accessing data and synchronizing it with the messaging broker is simpler and improves the quality of service and security.

The six IoT interfaces are common to the smart service layer and are dedicated to the sensors:

- the **Observable interface** allows services to be linked in a set, so the service schedule can provide these customers with these;
- the **DigitalSink interface** is designed for digital value sensors and two-way actuators (for example, on / off, true / false);
- the **DataSink interface** is dedicated to sensors with a complex data structure;
- the **AnalogSink interface** is the equivalent to the DigitalSink but with a float value;
- **EventSink** generates the events and their details that will be inserted into the meta parameter (for example, the fire alarm);
- The **AccelerometerSink** is a type of interface for accelerometers.

All information will be used to create the 3D model and to view all items corresponding to emergency situations, rooms, corridors, emergency exits, using smart glasses.

The emergency simulation will give users first-aid instructions when they use an Augmented Reality device by following the help instructions displayed on the device screen.

5. Conclusions

CitiSim is the ideal solution when it comes to smart city platforms because it supports the development and simulation of intelligent services within a common framework. In order to demonstrate the usefulness of the platform and the services it offers, more applications will be implemented in the field of smart energy, smart mobility, and smart emergency. Smart City is on the rise and has a huge impact on the economy. The benefits of CitiSim's exploitation are to the society represented by citizens and the economy, in terms of market values. The major innovation of CitiSim want to provide the first Smart City-specific platform to monitor in real time, and in 2D/3D a large infrastructure of the city and that enables to interact with users by developing/testing added-value and customized services in an agile and simple way.

Acknowledgement

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ICT pentru evaluarea și implementarea soluțiilor verzi

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Abstract

Scopul cercetării este de a identifica potențialele metodele informatice de evaluare și implementare a soluțiilor verzi în orașele inteligente. Obiectivele studiului sunt următoarele: (a) inventarierea metodelor informatice care prezintă potențial pentru evaluarea și implementarea soluțiilor verzi; (b) evaluarea caracteristicilor, principiilor de funcționare și a modalității de aplicare a software-urilor și a metodelor informatice care pot fi utilizate în scopul menționat.

Lucrarea elaborată se bazează preponderent pe conceptele de oraș inteligent (smart city), soluții verzi (nature-based solutions) și tehnologia informației (information and communications technology), cu accent pe modul în care acestea pot fi corelate.

În acest sens, se va realiza o analiză a diferitelor metode și instrumente și se vor identifica acelea care sunt considerate a fi cele mai eficiente în vederea evaluării și implementării soluțiilor verzi in orașele inteligente.

Vor fi identificate software-urile în funcție de dificultate, scara spațială și temporală, resursele necesare și eficiența în implementare a acestora. Astfel, în urma prelucrării datelor colectate au fost obținute o serie de informații grafice și tabelare. Rezultatele obținute permit determinarea potențialului de implementare a soluțiilor verzi ca modalitate de îmbunătățire a condițiilor socio-economice, în corelație cu dezvoltarea unui mediu agreabil pentru populație. Informațiile obținute în urma cercetării pot fi utilizate și extinse în studii de planificarea teritoriului și urbanism, informatică.

Cuvinte cheie: *Remote sensing, GIS, oraș inteligent.*

1. Introducere

1.1. Nature-based solutions (soluții verzi) – instrument al planificării urbane sustenabile și reziliente

Soluțiile verzi reprezintă acțiuni inspirate, sprijinite sau copiate din natură, implementarea acestora bazându-se pe caracteristicile mediului natural şi pe procesele complexe ce se desfăşoară în natură (European Commission, 2015). Conceptul este unul complex, fiind frecvent utilizat de către specialiștii din domeniul planificării urbane, precum și de către factorii de decizie (Fan, Ouyang & al., 2017), ca posibilitate de integrare a ecosistemelor naturale și a serviciilor aferente acestora în cadrul obiectivelor dezvoltării sustenabile (Lafortezza, Chen & al., 2017). Astfel, soluțiile verzi generează o serie de servicii ecosistemice care la rândul lor oferă beneficii legate de starea de sanogeneză a populației și de cadrul economic, contribuind semnificativ la atingerea obiectivelor legate de creșterea sustenabilității și rezilienței urbane (Niță, Badiu & al., 2018).

În contextul în care zonele urbane sunt supuse unor schimbări continue, caracterizate prin extinderea complexității sistemelor socio-economice și tehnologice, este necesar a fi identificate soluții integrate, eficiente și sustenabile. Soluțiile verzi oferă, prin integrarea factorilor sociali în cadrul principiilor privind conservarea biodiversității, susținerea activităților care contribuie la îmbunătățirea calității vieții și a stării de sanogeneză a populației urbane (Eggermont & Balian, 2015). De asemenea, contribuie la creșterea atractivității orașelor atât pentru rezidenți, cât și pentru potențialii investitori economici (Cohen-Shacham, Walters & al., 2016).

În această direcție, la nivelul Uniunii Europene se constată existența unui interes concret pentru dezvoltarea economică în strânsă legătură cu creșterea sustenabilității urbane, pe baza investițiilor în soluțiile verzi, aspect evidențiat în cadrul programului Orizont 2020 – Horizon 2020 (Maes & Jacobs, 2017).

Domeniile aferente soluțiilor verzi au identificate în cadrul Reportului EKLIPSE – Expert Working Group on Nature-based Solutions to Promote Climate Resilience in Urban Areas domeniile Nature-based solutions, acestea fiind în număr de 10 (Tabel 1.) (Raymond, Berry & al., 2017).

Tabel 1. Domeniile aferente soluțiilor verzi

Nr. crt.	Domeniu
1.	Rezilientă climatică
2.	Managementul resurselor hidrice
3.	Reziliența zonelor costiere
4.	Managementul spațiilor verzi urbane
5.	Calitatea aerului
6.	Regenerarea urbană
7.	Planificare și guvernare participativă
8.	Justiție și coeziune socială
9.	Sănătatea și calitatea vieții populației
10.	Oportunități economice și crearea de locuri de muncă

Sursa: *Raymond, Berry & al., 2017*

Din analiza proiectelor implementate în mediul urban, au fost evidențiate o serie de exemple de soluții verzi, și anume: (a) sisteme de drenaj cu scopul creșterii nivelului de infiltrare și retenție a apei în cazul suprafețelor permeabile, umede (Haase, 2015), (b) perdele vegetale, acoperișuri, terase și fațade verzi pentru controlul emisiilor de gaze cu efect de seră și combaterea efectului insulei de căldură (Fig. 1.), (c) plantări de arbori în zone cu densitate mare a construcțiilor, (d) grădini verticale (Baró, Bugter & al., 2016), (e) bioremedierea ca soluție pentru decontaminarea solurilor contaminate, (f) conversia funcțională a terenurilor abandonate sau a fostelor situri industriale (Panno, Carrus & al., 2017), (g) fitoremedierea ca soluție de depoluare a apei, aerului și solului (European Commission, 2015).

Figura 1. (a) Fațadă verde – orașul Toulouse; (b) Perdea stradală – orașul Toulouse
Sursa: *arhivă personală., 2018*

1.2. ¨Smart city¨ (oraș inteligent) – concept și implicații

Un oraș poate fi considerat ¨smart¨ în condițiile în care există un echilibru al dezvoltării mediului social, economic și ecologic, iar în același timp se promovează o guvernare de tip participativ (Yeh, 2017). Conceptul de ¨smart city¨ este utilizat pentru promovarea la nivel științific și guvernamental a unei dezvoltări urbane sustenabile (Artmann, Kohler & al., 2017).

Studiile elaborate în literatura de specialitate au identificat mai multe domenii de activitate relaționate cu dezvoltarea de ¨smart city¨, stabilindu-se, în acest sens, șase caracteristici principale: **economie ¨smart¨** face referire la competitivitate și productivitate economică, **populație ¨smart¨** indică resursele umane disponibile, **guvernare ¨smart¨** cu referire la participarea publicului, **mediu ¨smart¨** indică resursele naturale, **mobilitate ¨smart¨** se referă la transport și tehnologiei informației și a comunicațiilor (ICT), **locuire ¨smart¨** exprimă calitatea vieții (Fig. 2.) (Giffinger, Fertner & al., 2007).

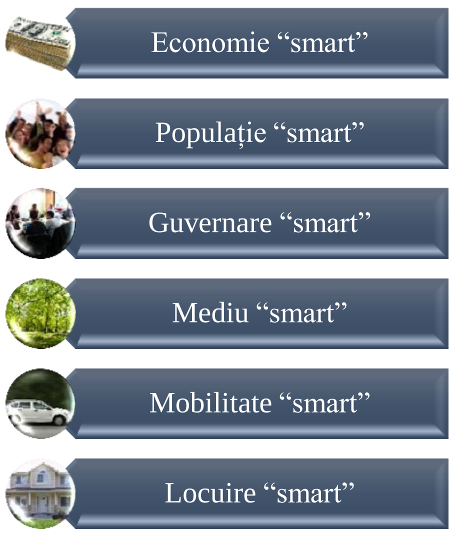

Figura 2. Caracteristicile unui oraș "smart"
Sursa: *după Giffinger, Fertner & al., 2007*

1.3. Utilizarea tehnologiei informației și a comunicațiilor (ICT) în cadrul unui ¨smart city¨

Procesul de transformare a unui oraș într-un ¨smart city¨ se bazează pe o serie de tehnologii, instrumente și metode viabile și funcționale (Fernández-Ares, Mora & al., 2017). Informațiile existente la nivelul orașelor inteligente se referă atât la datele procurate prin utilizarea de instrumente, metode și aplicații care conduc la obținerea de senzori, baze de date, cât și la alte surse promovate prin ICT precum aplicații mobile, cloud sau IoT (Internet of Things) (Fig. 3.) (Sta, 2017).

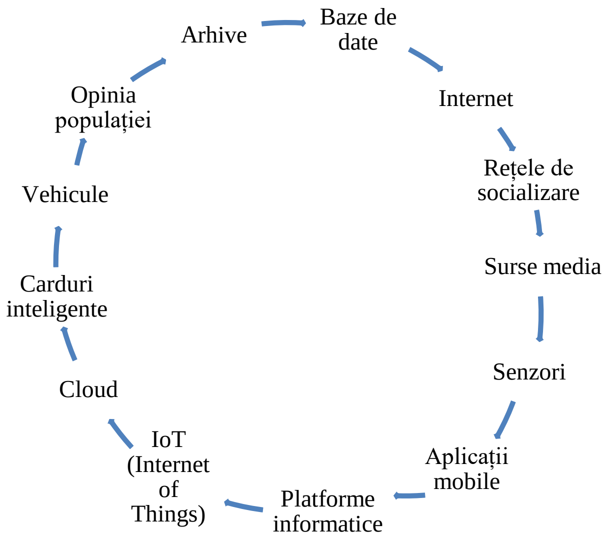

Figura 3. Tipuri de surse de informații
***Sursa:** după Sta, 2017*

Tehnologia informației și a comunicațiilor (ICT) oferă susținere atât în vederea dezvoltării unui oraș competitiv și inovator, cât și în tranziția spre un oraș sustenabil (Kramers, Höjer & al., 2014). Astfel, implementarea ICT în orașele inteligente reprezintă un punct de sprijin în utilizarea eficientă a resurselor (Sta, 2017) cu scopul dezvoltării urbane în acord cu creșterea economică, guvernarea participativă, îmbunătățirea calității vieții și a mediului (Yeh, 2017).

În Hilty, Arnfalk & al., 2006 au fost identificate o serie de sectoare de activitate în cadrul cărora ICT prezintă potențiale efecte asupra mediului, iar dintre acestea din perspectiva contribuției la evaluarea și implementarea de soluții verzi se pot evidenția următoarele: managementul deșeurilor (dezvoltarea de sisteme inteligente de valorificare a deșeurilor prin reciclare sau valorificare energetică), sisteme de transport inteligent (forme de mobilitate virtuală și managementul traficului), producere și consum de energie.

1.4. Geo - ICT în cadrul unui ¨smart city¨

Geo - ICT se referă la integrarea informațiilor spațiale în cadrul ICT (Aina, 2017). GIS (Geographic Informaton System) reprezintă un sistem de cartografiere utilizat pentru crearea, stocarea, gestionarea, simularea, procesarea și analiza unor cantități semnificative de informații geografice (Yang, Han & al., 2017), obținându-se rezultate prezentate atât sub formă grafică, cât și de raport (Tudose & Ovejanu, 2011). Dezvoltarea rapidă a instrumentelor și modelelor de analiză digitală din domeniul geo-științelor a determinat ca acestea să primească o importanță tot mai mare în procesele de planificare, politicile de protecția mediului, eficiența energetică, transport, scenarii de dezvoltare urbană. Metodele geografice de vizualizare 2D, 3D și 4D (¨geo-imaging¨) permit crearea unui cadru eficient de comunicare între factorii de interes implicați în procesele de planificare și dezvoltare urbană. Aceste metode implică o evaluare integrată și se bazează pe interacțiunea dintre tehnicile de analiză cantitative (self-organizing mapping, imagineering, data mining) și cele de analiză multicriterială (multi-criteria analysis) sau strategică (Kourtit, Nijkamp & al., 2017).

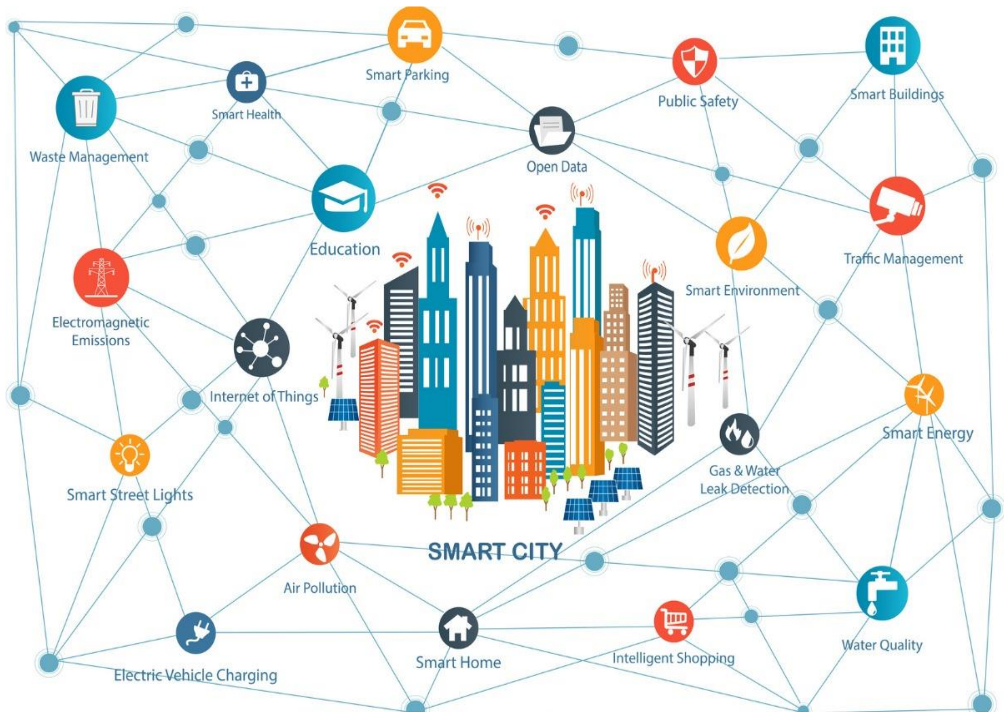

Figura 3. Relațiile de interconexiune existente la nivelul unui oraș inteligent
Sursa: *https://www.smartcitiesworld.net/news/news/smart-cities-services-worth-225bn-by-2026-1618*

Din perspectiva integrării soluțiilor verzi în cadrul orașelor inteligente analiza GIS poate fi utilizată pentru cartarea elementelor de proximitate (parcuri urbane, spații verzi rezidențiale, transport public, servicii), spațializarea extinderii spațiilor verzi la nivelul zonelor comerciale, industriale și rezidențiale (Artmann, Kohler & al., 2017). Din punct de vedere al mobilității urbane, prin intermediul GIS pot fi obținute informații legate de situația traficului și a rețelelor de transport (Yang, Han & al., 2017), evidențiindu-se modele de aplicații utilizate pentru managementul traficului (Aina, 2017).

2. ICT pentru evaluarea și implementarea soluțiilor verzi

Cu scopul stabilirii categoriilor de ICT pentru evaluarea și implementarea soluțiilor verzi au fost analizate cele 10 domenii aferente Nature-based solutions identificate în cadrul Reportului EKLIPSE, și anume: (1) reziliență climatică, (2) managementul resurselor hidrice, (3) reziliența zonelor costiere, (4) managementul spațiilor verzi urbane, (5) calitatea aerului, (6) regenerarea urbană, (7) planificare și guvernare participativă, (8) justiție și coeziune socială, (9) sănătatea și calitatea vieții populației, (10) oportunități economice și crearea de locuri de muncă (Tabelul nr. 2) (Raymond, Berry & al., 2017).

Tabel 2. Categorii de ICT pentru evaluarea și implementarea soluțiilor verzi

Domeniu	Soluție ICT	Descriere
Reziliență climatică	- Senzori de lumină - Ecrane LCD	- Senzori pentru limitarea consumului energetic - Monitorizarea consumului energetic
Managementul resurselor hidrice	- Baze de date digitale - Platforme digitale - Analiză spațială (GIS și teledetecție)	- Inventarierea, ierarhizarea și reprezentarea suprafețelor albastre
Reziliența zonelor costiere	- Baze de date digitale - Platforme digitale - Analiză spațială (GIS și teledetecție)	- Cuantificarea serviciilor ecosistemice
Managementul spațiilor verzi urbane	- Baze de date digitale - Platforme digitale - Analiză spațială (GIS și teledetecție)	- Inventarierea, ierarhizarea și reprezentarea suprafețelor verzi - Interconectarea infrastructurilor verzi și a infrastructurilor albastre, în vederea asigurării accesibilității acestora pentru populație
Calitatea aerului	- Baze de date digitale - Platforme digitale - Analiză spațială (GIS și teledetecție)	- Inventarierea, ierarhizarea și reprezentarea suprafețelor verzi - Conservarea și menținerea suprafețelor verzi existente
Regenerarea urbană	- Analiză spațială (GIS și teledetecție) - Instrumente de modelare - Open data sources	- Crearea unei interconectivități între diferitele categorii de soluții verzi existente sau propuse în spațiul urban - Crearea unei percepții pozitive a turiștilor sau investitorilor cu privire la un anumit spațiu prin promovare online
Planificare și guvernare participativă	- Baze de date digitale - Platforme digitale - Sisteme de măsură performante - Open data sources	- Platforme de cooperare între factorii interesați - Sisteme de suport a proceselor de luare a deciziilor - Dezvoltarea de procese de colaborare - Social media pentru diseminarea informațiilor
Justiție și coeziune socială		- Menținerea cerințelor și necesităților populației - Crearea de condiții corespunzătoare pentru grupurile sociale marginalizate
Sănătatea și calitatea vieții populației	- Analiză spațială (GIS și teledetecție) - Instrumente de modelare	- Realizarea unei planificări urbane astfel încât să se asigure o suprafață corespunzătoare de spațiu verde
Oportunități economice și crearea de locuri de muncă	- Sisteme de măsură performante - Baze de date digitale - Platforme digitale	- Instrumente digitale de calcul al impactului și eficienței soluțiilor verzi - Mecanisme finanicare inovative, achiziții inteligente, scheme de preț dinamice - Promovarea programelor de dezvoltare a competențelor - Creșterea nivelului de informare și conștientizare de către factorii interesați

Sursa: *Raymond, Berry & al., 2017; Mosannenzadeh, Bisello & al., 2017*

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