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INFORMATION TECHNOLOGIES FOR SMART CITIES

Abstract. The purpose of this article is to present the state of information technology in urban development. This is the result of a study of cities and city offices on the relationship between information technology and the state of Smart City development. At the beginning of this article the state of cities on the way to Smart Cities was presented. Then, the process of transforming cities into Smart Cities was discussed and the state of Smart Cities technology was described. Because the complexity of technology depends on the maturity of city offices, the relationship between technologies and maturity has been mentioned. Then, services were introduced as a way to decompose the technology. Based on the technologies, services and urban maturity presented, a key question for the development of Smart Cities was asked: how to assess technologies to be useful for the development of Smart Cities?

Keywords: Smart Cities, IT Technology, Internet of Things, Service Architecture

TECHNOLOGIE SMART CITIES

Streszczenie. Celem niniejszego artykułu jest prezentacja stanu technologii informatycznych w rozwoju miast. Jest to wynik badań miast i urzędów miast nad relacjami między technologiami informatycznymi a stanem rozwoju Smart City. Na początku tego artykułu przedstawiono stan miast w drodze do Smart Cities. Następnie omówiono proces przekształcania miast w Smart Cities oraz opisano stan technologii Smart Cities. Ponieważ złożoność technologii zależy od dojrzałości urzędów miast, wspomniano o relacjach między technologiami a dojrzałością. Następnie wprowadzono usługi jako sposób dekompozycji technologii. W oparciu o zaprezentowane technologie, usługi i dojrzałość miast postawiono kluczowe pytanie dla rozwoju Smart Cities pytanie: jak ocenić technologie aby były one przydatne dla rozwoju Smart Cities?

Słowa kluczowe: Smart Cities, Technologie informatyczne, Internet Rzeczy, Architektura usług

Introduction

The aim of this paper is the presentation of the status of IT technologies in Smart Cities. It is a result of the research on relations between suitable technologies and a Smart City position. At the beginning of this paper the state of the cities is presented. Next, the transformation of cities into Smart Cities from cities to the Smart Cities has been discussed. After that, the state of Smart Cities technologies have been described. Because the complexity of technologies depends on the Smart Cities maturity, the relations between technologies and maturity have been mentioned. Afterwards, services as a way of the technologies decomposition have been introduced. Based on technologies, the services and Smart Cities maturity, the question: how to assess the technologies and how to choose requirements for the Smart Cities?

1. The status of Smart Cities

The status of Smart Cities has been described with the consideration of 3 points of view – the first one: the city as a structure, the second one: the city as a complex system, and third one: the city as a group of services. Presented in this paper, the proposition (3 points of view) is a combination of theories on Smart Cities , a vision of a smart city as a complex system and implementation of this complex system as a set of services.

From the first point of view, a Smart City is defined as a place for combining: the creativity of citizens, the development of institutions that enhance learning and the field of innovation, and also as digital spaces facilitating knowledge transfer[1]. This place is supported by the innovation policies of the local government applied to design and implement Smart City initiatives[2] and by feed-back on the capacity of local government to innovate its organization and activities, including its services. Such heterogeneity of innovation depends on the city level characteristics and evolution of the services.

From the second point of view: the theory of the complex systems, especially the systemic theory of Smart City innovation is a place for innovation as an evolutionary and innovative process as a result of complex interactions among different actors, including public institutions.

[1] Graham S., Marvin S.: Splintering Urbanism. Routledge, London 2001; Komninos N.: The Architecture of Intelligent Cities Integrating Human, Collective and Artificial Intelligence to Enhance Knowledge and Innovation. 'The Architecture of Intelligent Cities', Intelligent Environments 06 Institution of Engineering and Technology, 2006, p. 13-20; Sotarauta M.: The Social Dynamics of Innovation Networks. Routledge, London 2014.

[2] Garica G.: Smarter as a New Urban Agenda. Springer, 2016; Lepouras G.: Encyclopedia of E-Commerce, E-Government, and Mobile Commerce. IGI Global, 2006.

The literature on public technology procurement emphasizes the role of the public sector in systemic innovation[3].

Smart Cities are also mentioned as a place for purchasers, end users of technology and as catalyzers of innovation. The differences in the nature, behavior and organization of the involved players, including the public sector, combined with the characteristics of technologies determine high heterogeneity of innovation processes across the countries and the regions[4].

The third point of view on Smart Cities presents them as the examples of service implementation which indicates the area of possible integration of the Smart Cities processes. It can be observed that literature on the diffusion of public eServices[5] and the frequent use of composite indicators (CI) in this field[6] has been growing fast. Most studies focus on eGovernment, whereas very few deal with other public e-services and none of them provides the assessment of national or regional performance of different public e-services. Many papers have developed the use of CIs data at the local level, but based on individual services and with low impact of the policy development level[7].

The examples provided in literature represent three different aspects of Smart City development. They also represent a common direction of Smart City expansion for variety actors and for the role of local government. Smart Cities are places driven by innovation for many areas represented as nodes of complex systems and managed by services.

2. Cities and the need of their changes

Nowadays more than 50% of population live in cities and by the 2030 population will have grown from 3.5 billion to 4.7 billion. It means also that districts, neighbourhoods and clusters are essential elements of a city, because a new city comes as a system of systems, and cities co-

[3] Edquist C.: The Systems of Innovation Approach and Innovation Policy: An account of the state of the art. Paper presented at the DRUID Conference. Aalborg, June 12-15, 2001, under theme F: National Systems of Innovation, Institutions and Public Policies; Hommen L., Rolfstam M.: Public Procurement and Innovation: Towards a Taxonomy. „Journal of Public Procurement", Vol. 9, Iss. 1, PrAcademics Press, p. 17-56.

[4] Fagerberg J.: The Oxford handbook of Innovation. Oxford University Press, 2005; Tether B., Metcalfe J.S.: Services and Systems of Innovation, [in:] Malerba F. (ed.): Sectoral Systems of Innovation. Cambridge University Press, Vol. 3, No. 3, 2004, p. 299-312.

[5] Arduini D., Bianchi A.: Patterns of public eService development across European cities. 2nd International EIBURS-TAIPS conference on: "Innovation in the public sector and the development of e-services". University of Urbino, April 18-19th, 2013,

[6] CEU: A Sustainable Europe for a Better World – EU Strategy for Sustainable Development, COM (2001) 264 final. Commission of the European Union, Brussels 15.05.2001; CEU: Environment 2010 – Our Future, Our Choice, the Sixth Environment Action Programme of the European Community 2001-2010, COM (2001) 31 final. Commission of the European Union, Brussels 24.01.2001; CEU: Communication on Implementing European Community Environmental Law, COM (2008) 773 final. Commission of the European Union, Brussels 18.11.2008; EC: European Union and European Commission Directorate – General for the Environment, www.europa.eu.int, 2010.

[7] Baldersheim H., Fimreite A.L.: Norwegian centre-periphery relations in flux: abolition or reconstruction of regional governance?. „West European Politics", Vol. 28, No. 4, 2005, s. 764-780.

exist within cities. Also 50% of the global GDP is produced in 600 cities. By 2025, 40% of global GDP growth will have been generated by middleweight cities in emerging markets. Demographic trends will increase and in 2050 the world population shall achieve 9bn. It means that the expansion of many megacities will be driven by the growth of populations and their achievements. It should be mentioned that cities consume two-thirds of the world's energy, 60% of its drinking water, and they produce up to 70% of CO2 emissions. Cities are aging societies: generation 65+ almost will have tripled by 2050[8].

The current structure of those cities is not efficient. If the cities have used $25 bn for welfare 30mfor Medicaid, SSA $450 bn to 44.3 m beneficiaries, $13 bn for public housing there should be effective tools of management. Red-tape: paper-based, costly, frustrating for providers and clients alike, fraud and abuse are the typical problems of those cities[9]. They need to proceed electronic benefit transfer but the processing cost for:

- Paper-based purchase transaction $120/transaction.
- An Internet/credit card $58/t.
- A proposed Internet/Intranet process model $18/t.

Then the cities need to assess challenges to be Smart Cities and to analyse some of the key research topics such as:

- Innovation studies: how does it work, how can we explain successes and failures
- Effectiveness of urban development strategies or interventions.
- Comparative research on different approaches to becoming a smarter city.
- Action research approaches, socio-technical systems change perspectives.
- Design and engineering practice studies in the living lab contexts.

Those analyzes are crucial for the city stakeholders who take part in the processes of city transformation. Citizens and citizen organisations, city administration and its departments, city planners and developers, research centres, Academia, energy and utility providers, automotive industry, facility control providers, non-governmental organisations and IT system integrators (processes and technologies) have been included to the process changing those Cities.

During the meetings of different stakeholders and discussions (not only via the Internet) the city administration and its departments (one of the stakeholders) suggest that the following challenges should be faced by the cities which want to become smart:

- Delivering cost efficiency.
- Eroded investments in services for citizens.
- Population growth = pressure on service quality.
- the role of the cities in carbon emission.
- Growing energy requirements = pollution increase.

[8] EEA: Europe's Environment – the Fourth Assessment, European Environment Agency. Office for Official Publications of the European Communities, Luxemburg 2007.
[9] Giffinger R., Gudrun H.: Urban Research & Practice.

- City congestion, efficient public transport.
- Needs to protect critical infrastructure.
- Aging urban infrastructure.
- Public safety and security.
- More demanding citizens – 'Digital natives'.

During such meetings and talks stakeholders understand that they are able to switch the city competition drivers for challenges. They recognize three of them as:

- To attract businesses, talents, skills (and taxpayers).
- Businesses are attracted into cities by the ease of operation and quality of life for Staff.
- The smart city ecosystem is a broad public-private partnership.

3. Smart Cities and their challenges

As it has been mentioned above , the minor challenges for successful smart city strategies are only possible to be met with skills, creativity, user-driven innovation, entrepreneurship, VC funding, and management of intra-government rivalries. The city decision makers try to find the smart city strategy based on Charles Darwin's idea that "It is not the strongest of the species that survive, nor the most intelligent, but the one most responsive to change" and define the following area of the Smart Cities.

The basic puzzle (mix) that policy-makers are faced with is how to adapt to changing environment, not just like driftwood in a stream but with purpose, and to implement the key EU policies as a consequence of the strategic adaptation. The following examples can be listed:

- Europe 2020 Flagship: Resource Efficient Europe;
- Low-carbon Economy 2050 Road Map;
- The European Commission White Paper 2011: Roadmap to a single European Transport Area;
- The European Energy Efficiency Plan (until 2020);
- Common Agricultural Policy and the Rural Development Programme;
- Common Fisheries Policy;
- Innovating for Sustainable Growth: a Bioeconomy for Europe, Strategy and Action plan.

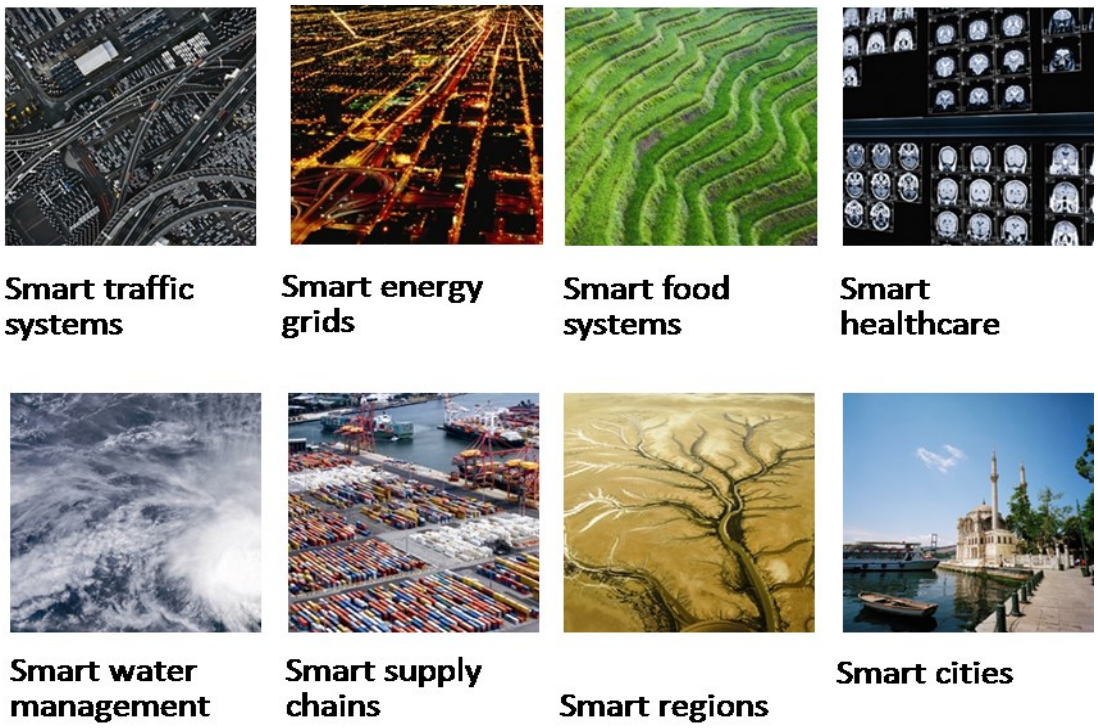

Fig. 1. Examples of the Smart Cities areas

It is possible that the EU funding shall stream to : FP7 for Research and Innovation, Horizon 2020, Trans-European Networks Transport (TEN-T),Intelligent Energy Europe Programme, Smart Cities and Communities Initiative and other founds[10]. It means also that governments and the EUcreates the central role of decision to develop the following ideas:

- The fortune of cities is linked to their Region and Nation.
- Benefit from Central Government's propulsion.
- One-stop shop City dashboard , journey planning, traffic accidents, energy level monitoring, crime prevention, non-critical reports, hospital waiting-list info.

Then the cities will have a knowledge compendium of the best practice: how to be smart and how to find the way to be smart. The decision makers understand that a smart city is more a urban strategy than urban reality, and there are numerous bottom-up initiatives besides some strategic planning, and infrastructure development. They also know that top-down planning and bottom-up initiatives should complement each other. The city hall is sometimes dominant, and there are also dilemmas of citizen engagement.

For this idea (engage all the stakeholders) we suppose that Smart Cities come as an environment to involve many (suitable for the stakeholders) technologies and applications. Then we will have many technologies (as an example of a decision) for Urban Transport, Problems for Noise, Emissions (Particulates & GHG), Crashes, Vibration, Energy Consumption, Visual Intrusion or Intelligent Freight Systems[11].

[10] CEU: Communication…, op.cit.; EC: European.., op.cit.
[11] Graham S., Marvin S.: op.cit.

4. Technologies for Smart Cities

Based on the current state of cities, Smart Cities challenges, stakeholders' requirements and benefits along with the policy issues for the technologies have been defined. They refer to regulation, deregulation, intellectual property rights, licensing, incentives, taxation, enforcement of rights and responsibilities. They also cover: advanced research, standards, security, social processes for the adoption and the use of IT infrastructure and risk management among the constellation of providers and carriers (networks, content, cable, broadcast, wireless voice and data, and telephone). For such conditions and concentrations of the technologies applied for Smart Cities, it is possible to define the basic terms as intelligence and integration. Intelligence means: gaining knowledge (data collection and information processing), analysing (sensing and analysing environment, detecting changes, perceiving problems), making decisions (acting rationally, choosing solutions and learning (using experience to make improvements, identifying new problems and decision making). The global view for technology implementation is presented in Figure 2.

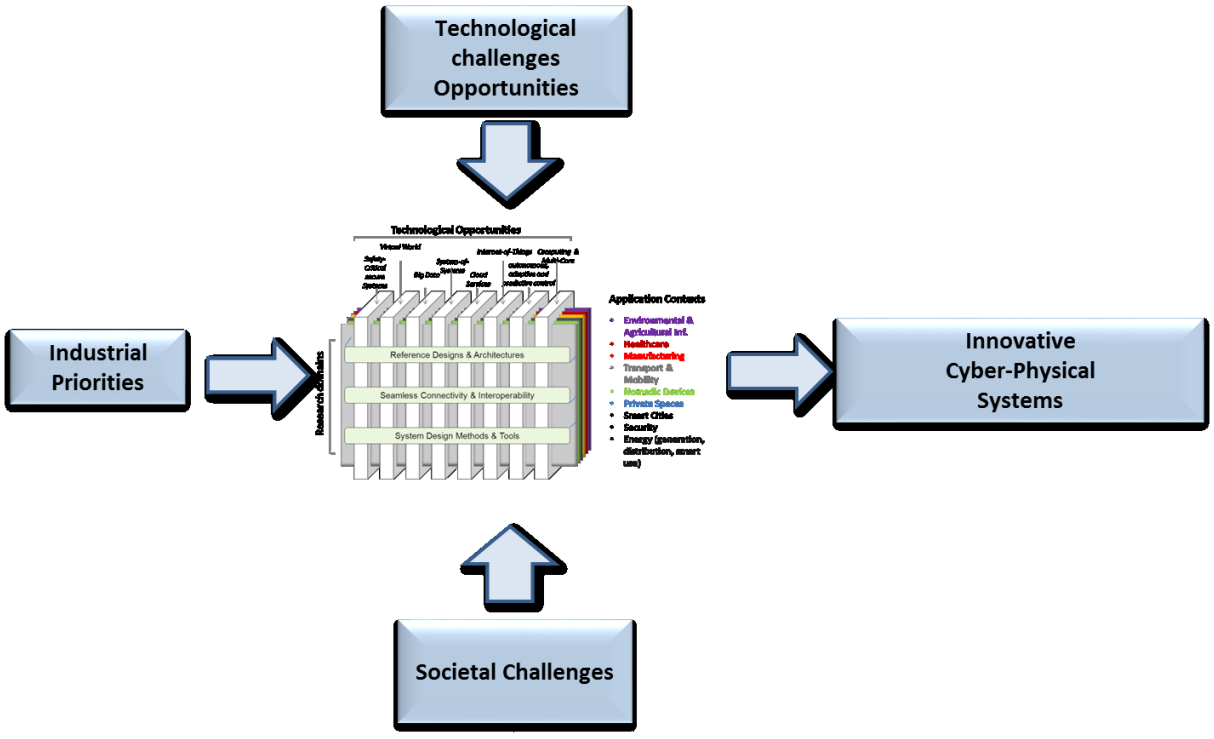

Fig. 2. The general view of using technology for Smart Cities

Technological challenges (Figure 2) include different types of IT systems and applications. Generally, applications are classified into the following groups:

- big scale applications
  Smart buildings, smart transportation, smart homes
  Sensing for Climate change prediction and adaptation
  Global scale, heterogeneous, specialized for location, challenging environments
  Correlation of sensor data which does not even measure the same things
- middle scale applications
  Distributed systems
  Synchronisation, communication, scalability, middleware
  Mobile Systems
  Pervasive computing, sensor systems, mobile services
  Embedded and hybrid systems
- mixed scale applications (based on services)
  Energy efficiency issues at all levels
  Including sensors, mobile devices, client/server systems, data centers, cloud.
  Sustainable IT and IT supporting sustainability.
  Issues of large scale implementation of science via IT systems

5. Examples of smart system technologies

Smart Cities need technologies which deeply the city infrastructure and service life cycles and which will be also impacted by their Internet of Things deployments. The CIOs and CTOs city departments must also plan the bus communication for all technologies or all services. Below some examples of those types of technologies divided in some groups are presented .

The first example refers to smart grids and energy efficiency (cities consume between 60 and 80% of world's energy)[12]. A Smart Grid with smart measuring sensors allow us to monitor and to adjust generation and delivery based on consumption models. Applying this kind of energy reduces costs and negative environmental impact.

The second example is intelligent transportation: which allows a city to maintain its activities. This system works in real-time traffic flow information and it applies: Telco, Global Positioning Systems (GPS) and M2M communication with Wi-Fi and RFID technologies. The system of such data analysis and prediction techniques are also involved.

The third example is the Connected Healthcare system. This system consists of secure collaborative access for authorised medical services to Electronic Patient Records, in any possible way, at any time, from anywhere, by any accredited device. This system applies also

[12] Baldersheim H., Fimreite A.L.: op.cit.

telemedicine solutions for remote areas or in case of natural disaster. All those types of systems require privacy, identification and cyber security.

The fourth system is public safety and security. This system concerns the following issues:

- Protection against crime, natural disasters, accidents or terrorism.
- Tele-surveillance systems to help emergency services.
- First respondents to benefit from secure connectivity.
- Secure data access and sharing.

All the systems are based on wireless communications & hotspots technologies (Fig. 3) which include:

- Increasingly popular service, with increasing vulnerability.
- Unsecure access to sensitive and personal data (online banking, social network, etc).
- Younger population particularly exposed.
- Cyber-crime increasingly active in these environments.

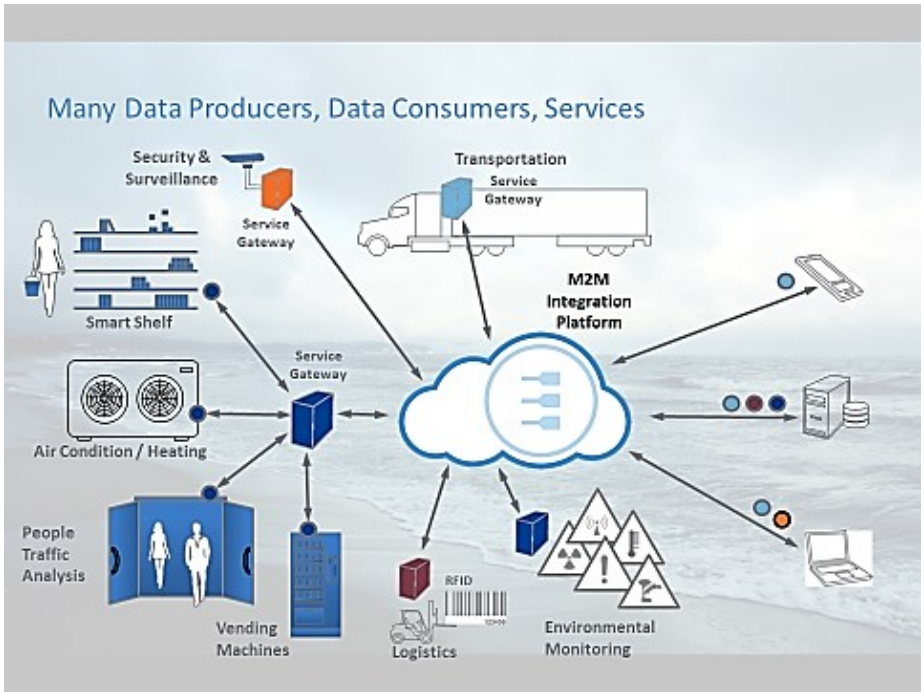

Fig. 3. Example of wireless communications & hotspots technologies applied in Smart Cities systems

6. Technologies applied in Gdansk – examples

The examples of the above-presented technologies and services they provide have been already mentioned. Those technologies have been used in the environment of the IT project Eureka Air quality management in urban areas using a Web Server E!3266. Fuzzy decision-making scenarios were created in that project, which were then implemented in the Webair_PM

decision-making system developed for various Smart Cities projects. When preparing data for the project, a precise description was developed, including both data and the database system. Two different solutions were taken into account in terms of database construction strategies. In the first solution, the direct feed of data from the project partners to the Webair_PM system was assumed. The second solution was based on building a data warehouse powered from external databases of the project partners. Before choosing a solution, both versions were tested.

On the one hand, the first situation required an analysis of the different database standards, on the other hand however, the possibility of feeding the constructed system with data of varied standards. Therefore, two experiments were carried out. In the first one, data requirements and standards were specified (Armaag – pollution data, the City Council – noise data, Gdansk University of Technology – pollution and weather conditions.) A parallel database feed via Webair_PM was also carried out[13].

It soon became apparent that the parallel feed was very difficult to implement, and therefore it was decided to perform the initial feed with batch data (experiment II) to assess the suitability of the data and the mechanisms of its acquisition. In the case of batch processing, there was no problem with obtaining the data, but there was a problem with reproducing the batch feed. Therefore, a more complex solution was found which involved building an external entity in relation to the Webair_PM system, namely a data warehouse. The processes for supplying both the warehouse and Webair_PM were developed. Although the mechanism proved to be useful for Webair_PM, it was not possible (for data from Armaag) to provide a continual new data feed to the warehouse.

The standard of the data warehouse was also analysed. Two file standards, *.SQL and *.DB2, were taken into account. From the point of view of Webair_PM, the better solution (meeting the requirements of Webair_PM) was the former standard. However, the experience of the team members was taken into account, as they were not familiar with the DB2 standard. Therefore, the SQL standard was finally chosen, although DB2 seemed to be more developmental. The decision to choose a more familiar standard over a more predictive one stemmed from the need to reduce project risk. The diagram of the data integration processes of the Eureka project is shown in Figure 4.

[13] Kowalczuk Z., Orłowski C.: Advanced Modeling of Management Processes in Information Technology. Springer, 2014; Orłowski C., Kowalczuk Z.: Modelowanie procesów zarządzania technologiami informatycznymi. Pomorskie Wydawnictwo Naukowo-Techniczne PWNT, 2012.

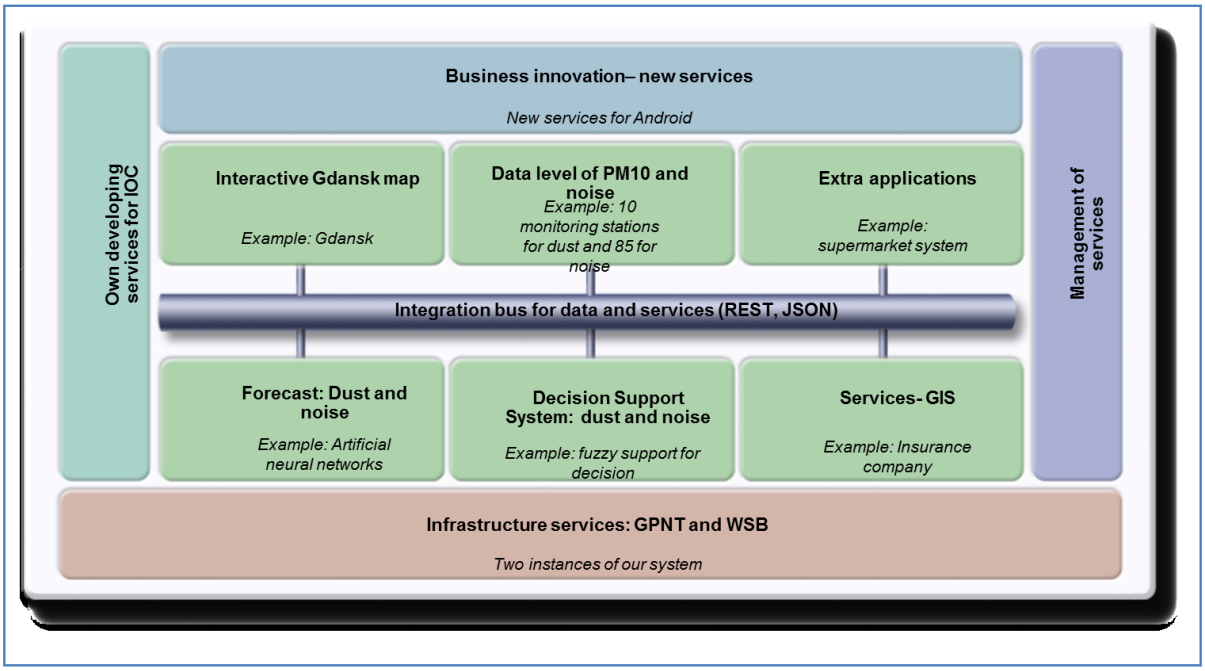

Fig. 4. Services Architecture – Enterprise Service Bus

The study of replicative validity involved identifying the components of the model (the database system and integration technologies), the relationship between these components as well as demonstrating that the integration technologies control the process of developing a decision-making system. The identification of two components proved to be relatively simple (the resource of the SQL standard database, the data integration processes and data warehousing), however, the relationship between these two components proved to be a much more complex problem. To support it, it was necessary to create a database trigger for the data warehouse. It turned out that its use facilitated the flow and the feed through the ETL processes.

In the process of replicative verification, it proved equally difficult to demonstrate that the use of a data warehouse was a controller of change in the processes of constructing the Webair_PM decision-making system. The transition between the different integration technologies observed during the construction was a process resulting from the experience of the managers of the project rather than from a sequential process of formal changes. Therefore, the replicative verification process should be considered partially successful.

7. Conclusions

In this paper Smart Cities technologies have been presented. At the beginning the processes of the cities have been described as an introduction to the process of Smart Cities described later. The first part of the article particularly focused on both processes to assess the state of the cities suitable to implement the IT technologies.

The current structure of the cities is not efficient. In the paper some examples which involve the welfare, medical aid and public housing have been mentioned. It means that the cities should change the processes to more effective processes of management. Then the phenomenon of the Smart Cities processes (as an answer to the processes of inefficient cities) have presented in this paper.

The Smart Cities processes should be supported by suitable technologies. It means that we should assess the state of Smart Cities. In this paper this city state has been described from 3 points of view: first as a structure, second as a complex system and the third as a group of services.

Such a description of the types of technologies which we should use for the stakeholders in the Smart Cities has been introduced. The Smart Cities processes are also discussed (considering 3 points of view): advanced research, standards, security, social processes for adoption and the use of IT infrastructure and risk management among the constellation of providers.

According to those processes, appropriate technologies have been presented. Fourth examples of such technologies (for the processes) have been shortly mentioned (smart grids and energy efficiency, intelligent transportation, connected healthcare system, public safety and security).

The Author adds an example of the technologies used in Gdansk agglomeration. Those technologies provide/include services. Those technologies are used in the environment of the IT project Eureka Air quality management in urban areas using a Web Server E!3266 for fuzzy decision-making.

Based on the above-presented analysis of the cities, Smart Cities and suitable technologies for the Smart Cities, it is possible to draw some general conclusions

- If we started to assess the Smart Cities technology we would have to assess the readiness of the Smart Cities to implement those technologies in the cities. It is a question how to assess the readiness of a smart city? If we evaluated readiness in the specific areas of the Smart Cities we would need to appraise the processes. If we knew those processes we would need to fit the technology for those processes.
- The readiness of the Smart Cities to implement technology means also that the cities are ready to implement those technologies as services. The services express not only the technologies. They also indicate decomposition of the city processes to the minor aspects of the proper decisions in the complex city processes.
- The decisions of the cities depend on the data obtained from many measuring devices. If we implemented technology as Internet of things in the cities we would find the appropriate data from many qualitative sensors. Then we could assess not only IT technologies but also the measuring devices to deliver big data for decision makers.

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