An Industry Perspective on Smart Cities: A Smart City Process Framework

Márcio Egydio S. Rondon, Fabio L. Fonseca, Andre Maximo, Felipe M. Costa, Isela Macía, Paulo G. Rodrigues, Marcelo Blois

GE Global Research – Brazil Technology Center
Rio de Janeiro – RJ – Brazil

{rondon,fonseca,maximo,f.costa,bertran,gallotti,blois}@ge.com

Abstract. *The smart city domain is receiving a lot of attention from the software community around the globe. The reason is that city population is growing in fast pace and new solutions and software techniques are required to enhance citizens' quality of life and avoid a city breakdown. This paper proposes a process framework to clarify the main processes of a smart city and, therefore, pave the way for applying software knowledge into the smart city domain. Based on this framework, we derive a classification system to improve the understanding of current smart city projects. In this system, each category represents an instance of the framework. Finally, we classify smart city projects using the envisioned system, as an example of its utilization.*

1. Introduction

Urban areas are rapidly growing during last decades. According to OVUM (2013), in 2009 more than a half of the world population was concentrated in cities, where 320 million people were living in 21 megacities - i.e. cities with more than 10 million people. OVUM predicts for the end of 2050 an average of 84% population growth in cities, with 29 megacities housing 470 million citizens. This growth highlights a need for reviewing city processes and services because complex congregations of people inevitably tend to become messy and disordered [Johnson 2008].

Megacities generate a number of new issues, such as traffic congestion, waste management difficulties, scarcity of natural resources, inadequate housing and infrastructures, air pollution and healthcare concerns [Mitchell 2007; Marceau 2008; Toppeta 2010]. In this context, the concept of *smart cities* emerges as a redefinition of the cities fundamentals, aiming at addressing these problems and improving the overall citizens' quality of life. Although there is no consensus among practitioners and researchers regarding this concept, all of the proposed definitions rely on the ideas of sustainability, collaborative work and the use of technology to make a city smarter [Hall 2000; Washburn *et al.* 2010; Chourabi *et al.* 2012].

Given the opportunities that rise in this scenario, many companies are providing advanced technologies to support the implementation of the smart city concept, such as GE, IBM and Siemens. The solutions provided by these companies have been adopted in several cities, as highlighted in Section 3, but there is no system that helps to classify and understand the common characteristics of these solutions. Specifically, a system allowing researchers and practitioners categorize smart city solutions according to their functionalities, processes, benefits and limitations. Although some researchers aim at ranking cities according to their smartness degree [Bigliani *et al.* 2011, Smartness degree 2013], they do not focus on classifying individual projects that have been implemented in the smart city context.

To tackle this problem and inspired on concepts of software, we propose a framework based on processes observed in existing smart cities solutions, which are: Monitor, Analyze, Predict, Visualize and Act. Instances of the framework correspond to the relationships that can be established among these processes, creating categories for a classification system. Additionally, we illustrate how such system can be used in practice by classifying several smart cities projects into five different categories. This classification allows researchers and practitioners to differentiate between the projects and clarifies the view about their main processes.

This paper is organized as follows. Section 2 introduces concepts related to smart cities according to the literature. Section 3 presents companies and institutions that are currently playing an important role in the smart city context as well as some relevant city-wide projects, hereafter referred as *smart city cases*. Section 4 describes the proposed process framework, how it can be instantiated and classifies the players solutions discussed in Section 3 according to the proposed framework. Finally, Section 5 presents the conclusions.

2. Background

As discussed in [Chourabi *et al.* 2012], the concept of a smart city is still emerging and several authors have proposed definitions for it. Among the definitions, Hall (2000) states that a "*Smart City is a city that monitors and integrates conditions of all its critical infrastructures, including roads, bridges, tunnels, rails, subways, airports, seaports, communications, water, power, even major buildings, can better optimize its resources, plan its preventive maintenance activities, and monitor security aspects while maximizing services to its citizens*". Washburn *et al.* (2010) defines a smart city as "*the use of Smart Computing technologies to make the critical infrastructure components and services of the city more intelligent, interconnected and efficient*". Other definition, from Dirks and Keeling (2009), looks to a smart city as an organic integration of systems, taking into account the interrelation of its subsystems, using a system of systems point of view.

Practitioners overuse the smart city concept as a marketing tool, to label and add value to products and services. The first smart city cases focused on creating new places, such as Masdar in Abu Dhabi (2013). These places were designed from scratch, with all kinds of green and sustainable concepts and are known as *top-down* [Siegele 2012] cases. Nowadays, a new vision for smart city cases is being considered, aiming at turning a regular city into a smart one in an incremental way – i.e. *bottom-up* cases. Amsterdam is an example of a bottom-up case, with several smaller projects, contributing to raise its citizen's quality of life.

3. Current Smart City Initiatives

This section provides a better understanding about current smart city initiatives. Section 3.1 presents initiatives of who we call *smart city players*, which are companies that offer smart city solutions. Section 3.2 describes four relevant smart city cases around the world: Santander, Amsterdam, San Diego and Rio de Janeiro.

3.1. Smart City Players

All the companies mentioned in this section have in their commercial portfolio solutions that can be used to make cities smarter. Additionally, we focus on companies whose contributions have been widely recognized in the smart cities scenario [Cleantechinvestor 2013, Gartner 2013, Greenbang 2013]. Taking into consideration these criteria, the following nine companies were selected: GE, IBM, Siemens, Cisco, Ericsson, Libelium, Living PlanIT, Oracle, and Schneider Electric.

In the context of smart cities, two **GE** initiatives stand out: *Ecomagination* (2013) and *Healthymagination* (2013). *Ecomagination* aims at investing on innovative solutions to environmental challenges, delivering energy-efficient products and services to customers. *Healthymagination* is committed to making sustainable health a reality. Its goal is to bring high-quality care at lower cost to more people throughout the world.

Solutions of both initiatives have already been implemented in many cities around the world, such as San Diego, Madrid, Barcelona, Albin and Rotterdam. The solutions address needs in the following domains: building, energy, water, mobility and public safety [Ecomagination 2013, Healthymagination 2013]. As examples we highlight three solutions, two in the mobility domain and one in the building domain. The first mobility solution is located in Italy, where GE designed and installed an automatic train protection system, guarantying that the maximum speed limit is not surpassed. The other solution takes place in Barcelona's metro, where a central control room that monitors the status information of all escalators, elevators, ventilation and lighting. Regarding the building domain, GE installed an integrated security system in the Hungarian House of Parliament. This building solution provides access control, intrusion detection, building surveillance, fire detection and video surveillance functions from one single shared platform supported by graphical maps.

IBM (2013) is a well-known smart city player, having a portfolio mainly based on software solutions. The company groups the main city pillars in three fundamental domains: *Planning and Management; Human; and Infrastructure*. In the context of Smart City solutions, IBM offers a suite of products defined as Intelligent Operations Center. The goal of this suite is to: (i) monitor agency and citywide operations, (ii) involve citizens and businesses in incident reporting and resolution, and (iii) gather and analyze citizen feedback using social media. Intelligent Operations Centers have been implemented in several cities around the world, such as New York in US, Gauteng in South Africa and Rio de Janeiro in Brazil [IBM 2013]. In particular, for the center in Rio de Janeiro IBM contributed with a weather radar and a prediction model customized to Rio's environment. This device is able to anticipate climatic events up to 48 hours ahead, allowing the city to position defenses in place to diminish their impact.

Siemens (2013) is an important player on Smart and Sustainable Cities. Siemens acts in the following areas: renewable energy, smart buildings, intelligent lighting, electric car infrastructure, smart grid applications, safety and security, healthcare, as well as waste and water treatment [Siemens 2013]. *The Crystal* is the Siemens' Sustainable City initiative aiming at showing their portfolio of solutions for a smart city. It is a building that combines different technologies with the purpose of supporting a reduction of energy consumption, intelligent lighting as well as waste and water treatment. The goal is to provide a global knowledge hub that helps a diverse range of audiences learn and understand how they can all work to build better cities for today and for future generations. Siemens' solutions have been also adopted in several cities around the world. For instance, in London Siemens provided a fleet management system to track buses and trams operations using traffic signal prioritization [Siemens 2013].

Cisco uses the term *Smart+Connected* Communities (2013) to refer to smart cities related solutions. The main focus of the company is on network infrastructure, providing solutions such as video conferencing, Closed-Circuit TV cameras, fiber network connectivity, IP telephony and Wi-Fi. Cisco has been involved in several Smart Cities cases. For instance, the company takes part of the Amsterdam Smart City case [Green 2011], acting as an Information and Communication Technology (ICT) infrastructure provider for the smart home project. In this project, Cisco was in charge of promoting the integration among home owners, IT companies, energy companies, installers and application providers focused on energy saving.

Ericsson is also a global reference on network infrastructure focused on mobile networks. The company uses the term *Connected City* (2013) to refer to smart cities related solutions. Based on its products, the company developed specializations of the term, such as Connected Home, Connected Building, Connected Hospital, Connected Bus, Connected Truck, Connected Outlet – for electrical vehicles (EVs) charging stations – and Connected Substation. Examples of solutions applied to this variety of contexts are bi-directional mobile connectivity, real time connectivity, secure device identification and online visualization. In the context of smart cities, Ericsson is noted by its traffic management solutions, which have been implemented in several cities, such as Zagreb, Rijeta and Munich [Mppi 2013].

Libelium is a provider of hardware and software for wireless sensor platforms. The company produces an open source sensor platform for the Internet of Things [Ashton 2009] to support the system integration as well as the implementation of machine to machine solutions for end users. Examples of applications built using Libelium's solutions are smart parking and smart irrigation solutions. Moreover, Libelium's solutions have been adopted in several cities such as, Santander, Valencia, Salamanca, Asturias, Belgrade and Panveco. In particular, Libelium provided the sensor nodes hardware used in the Smart Santander project, presented in Section 3.2.

Living PlanIT has the so called Urban Operating System (UOS), a software platform solution built on the ideas of sensor-based data acquisition, real-time control, historical database and an analytics engine hosted in a cloud environment.

Oracle has a City Platform Solution (2013) that is a Smart Cities initiative, which integrates the company products applied to this context. Examples of these products are: CRM, SOA, BPM, Database, IDM and Content Management platforms.

Schneider Electric has a smart cities product portfolio based on Geographic Information System (GIS) and IT Systems solutions and a Supervisory Control and Data Acquisition (SCADA) platform for pipeline, energy utility, transportation, agriculture and environmental monitoring industries. The company is also a player on the Smart Grid domain, providing solutions such as distribution network management and smart metering. Additionally, Schneider has weather platforms that include weather decision support solutions, Automated Terminal Information System (ATIS), Automated Weather Observation System (AWOS) and weather stations.

3.2 Smart City Cases

This section presents four smart city cases with two common characteristics: (i) they are city triggered initiatives, in other words, projects demanded by the City Hall that are part of a smart city program for the municipality, and (ii) they involve multiple companies and institutions.

The first analyzed case is **Smart Santander** (2013). The idea behind it is to build a smart city infrastructure through the use of wireless sensor networks that: (i) provides services to citizens and (ii) supports the realization of large scale experiments [Galache *et al.* 2012]. In order to provide these two parallel features, the wireless sensor nodes have two wireless interfaces. The first one is dedicated to the services and implements the proprietary digimesh networking protocol. The other is dedicated to the experiments and implements native IEEE 802.15.4. Through over the air programming (OTAP), the platform allows external developers to load their programs and run experiments on-the-fly. Examples of services provided by the system are environmental monitoring, such as CO level, luminosity and temperature measurements and data related to the availability of parking spots.

Another relevant case is the **Amsterdam** Smart City (2013). This case acts in five city domains (or themes) and comprehends thirty two projects spread over the city. Projects are classified by the domain, i.e. living, working, mobility, public facilities and open data. The projects encompass solutions with different purposes such as smart grids, local energy generation, and energy management by the user, car sharing, electric vehicles, telepresence conference centers, smart lighting, smart building technologies and application development for dealing with the city's open data. The three city areas which are the focus of the project are Nieuw West, Zuidoost, and IJburg, but the projects are not geographically limited to them.

The strategy of this case is to use the city as an urban lab, allowing business to test and demonstrate innovative products and services, and aiming at implementing the most effective solutions on a large scale in a near to mid-term time scale. Examples of high-level objectives of the project are energy saving, CO_2 emissions reduction as well as sustainable economic growth and innovation promotion. The partnership for the development of this case was established among businesses, city authorities, research institutions and citizens. In particular, citizens are involved in open calls for proposals and in volunteering programs to participate in innovative technologies tests (e.g. using energy smart meters for observing their energy consumption behavior pattern and comparing it with their behavior with ordinary meters). The case counts on the contribution of multinational companies such as Cisco and Accenture, and service providers such as KPN, as business partners. On the research institutions side, the Center for Energy Studies from the University of Amsterdam is a partner.

The third analyzed case is **San Diego** Smart City (2013). This case is mainly composed of energy-related solutions. Its priorities can be summarized as to: (i) support California's goals for localized electricity generation and 33 percent renewable energy by 2020, (ii) empower consumers with real-time knowledge and intuitive technology to manage their energy use, (iii) minimize the need for additional infrastructure by optimizing and automating the electric grid with two-way communications and monitoring technologies, and (iv) demonstrate the value and impact of innovation to the San Diego region and the community through public smart grid solutions and displays.

In order to implement the case, integrated smart city solutions were thought for seven big domains, i.e. energy, water, healthcare, public safety, transport, buildings, and waste. Similarly to the Amsterdam case, a partnership among the city government, businesses, education, and non-profit organizations was established. On the business side, the group was composed by GE and the local energy service provider, San Diego Gas & Electric (SDGE). The education partner was the University of California San Diego (UCSD) and CleanTech San Diego, a non-profit organization, also took part in the case. Some examples of the projects that compose this case are (i) the *Car2go*, a plug-in EV sharing pilot; (ii) *San Diego Zoo*, which installed solar photovoltaic canopy, able to charge EVs in the zoo parking lot; (iii) *photo voltaic* (*PV*) *Integrated Energy Storage*, a grant application to test, demonstrate and evaluate PV integrated energy storage projects; and (iv) *Smart appliances*, where the objective is to test the communication links between GE smart appliances and SDGE's smart meters.

Finally, in **Rio de Janeiro**, the city hall built an integrated Operations Center (2013) to control traffic and weather aspects of the city. The relevance of the operations center is given by the fact that it integrates different stages of city crisis management, from prediction and preparation to immediate response to incidents like rainfalls, landslides and traffic accidents. Nowadays, the center combines information from more than 30 cities and state agencies as well as private utilities and transportation companies. Dozens of operation managers are dedicated to monitor images and data on a real time basis, which are mainly related to weather, traffic, police and medical services.

4. Smart Cities Framework

Several global rankings [IC 2013, GCI 2013] and regional indexes [Bigliani *et al.* 2011] have been proposed to classify cities according to the overall citizen's quality of life, carbon footprint, integration and use of communications, among other factors. These rankings, however, focus on the city as a whole and do not classify smart city projects separately. In order to fill this gap, we propose a process framework that can be instantiated in a city. These processes are derived from the concepts Monitor, Analyze, Predict, Visualize and Act, leveraging the knowledge related to them into the smart city domain. Additionally, instances of our framework can be used as a mean to improve the understanding about projects in the area of smart city. Figure 1 depicts the processes that make up our framework, the relations among them and their interaction with the city environment.

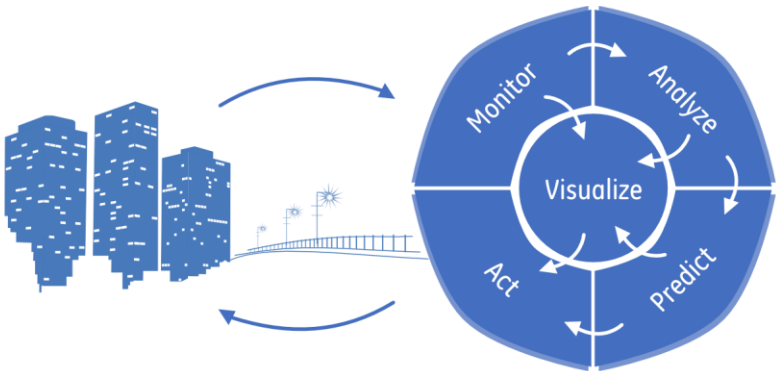

Figure 1: Framework conceptual model.

4.1. Framework Processes

The proposed framework has five processes based on the concepts of Monitor, Analyze, Predict, Visualize and Act. These processes are described below.

The **Monitor (M)** process comprises the collection and storage of state data by a monitor over an agent. The monitor is the entity responsible for collecting data from the agent, which can be a person, a system or a device. Data collection can be performed automatically or manually, in other words, by a human agent. The automatic collection modes can be defined as monitor poll or agent push. In the first mode the monitor polls the agent in a predefined time interval to retrieve its state, whereas in the second one the agent pushes data from itself to the monitor. An example of the Monitor process is the measurement of temperature in a given part of a system. This information can be automatically obtained through the use of sensors collecting the instantaneous temperature in a predefined interval and storing it in a data repository for further analyses. Such temperature collection could be also performed manually by a human and stored in the same way.

The **Analyze (An)** process encompasses multiple aspects of data processing. In particular, the process aims at transforming raw data gathered from the Monitor process into understandable information. Information can be defined as data that is processed, organized or presented in a given context so it is useful. Information analysis relies on the applications of statistics, computer science and mathematics to convert data into information. It might demand the use of extensive computational resources to analyze large volumes of data coming from many different sources. An example of analysis is calculating the average temperature based on the raw samples collected in a predefined time interval and comparing it to the expected value threshold for a given equipment.

The **Predict (P)** process encompasses the ability to foresee problems and situations that not yet happened. The process relies on: (i) a model for prediction and (ii) the previous analyzed information that can be used for simulation, optimization and what-if scenarios. Due to a city be a complex environment that changes continuously, its predictive models should be adaptable and dynamic, considering these continuous changes, new rules and all the aspects that represent the city. Depending on the predictive tasks, the Predict process can run in real-time synchronized with the Analysis process, or in a batch mode, aiming at discovering long-term trends.

After performing the previous processes, decisions can be made to optimize the city operation. The **Act (Ac)** process aims at changing the city state in order to achieve the desired optimization. The process can be performed by an automated system or by a human agent. An important aspect to be taken into consideration when modifying a live city is the validation of its state prior to the change enactment. Another important aspect of the Act process is security. Modifications to the city must only be enacted if coming from a predefined safe source. For instance, if the control network is connected to the Internet, very special attention should be paid to avoid security breaches that could compromise the whole city operation.

The **Visualize (V)** process is the convergence of all previous ones in a human-supervised interface used for understandability and decision-making support. The process is responsible for transforming data and information from various forms into texts, audios, images or videos that better convey the original information. While raw data from monitoring devices are transformed into beep signals and graph images, knowledge derived from analyses or predictive models is converted to text alarms and simulation rendering videos. It is through the visualization of monitoring devices, processing analysis and predictive models that an external user has a basis to decide when to act in the system. Therefore, it is important that the provided visualization is accurate and convey proper and unbiased information.

4.2. Framework Instantiation and Classification System

The proposed framework can be instantiated in two different ways. The first way is related to how each process is implemented according to the particularities of the city. For instance, a city can implement the automatic monitoring of devices, while others cities carry out a manual monitoring. The same applies for the remaining processes. The second kind of instantiation regards to how the processes relate to each other. For instance, a city can only implement Monitor and Analysis processes, while another city implements these processes and also the Predict. In particular, we focus on the second kind of instantiation in this paper.

This section presents five instances of our framework, which can be seen as a classification system in a holistic way. Classification systems are essential to more accurately guide the evolution of a research area, helping to organize the knowledge and to foresee research gaps. These systems can also be used to classify research areas according to their "maturity level". The goal of the proposed system is to improve the understanding of current projects that have supported the smart city concept. Specifically, the system can support practitioners and researchers in the identification of the strengths, weaknesses and, hence, improvements in these existing projects.

Considering the processes and the relationships among them illustrated in Figure 1, five main instances emerge: *M-V-Ac*, *M-An-V-Ac*, *M-An-P-V-Ac*, *M-An-Ac* and *M-An-P-Ac*, where the letters correspond to the framework processes. Each of these instances constitutes closed loops in a feedback control system and plays the role of a category in our classification system. These instances are detailed below.

The *Monitor-Visualize-Act (M-V-Ac)* is an instance of the framework that corresponds to what the industry refers as the SCADA system [Boyer 2009]. This system is widely used in utility facilities in a city, such as electrical energy.

The *Monitor-Analyze-Visualize-Act (M-An-V-Ac)* and *Monitor-Analyze-Predict-Act (M-An-P-V-Ac)* instances are based on a customized version of the Monitor-Analyze-Plan-Execute-Knowledge (MAPE-K) control loop of the Autonomic Computing area [Kephart and Chess 2003]. The difference between these instances is that the second one considers the Predict process. Both instances can be defined as supervised once they consider visualization as part of the flow. The visualized information can be used by a human agent to support decisions about which kind of actions need to be performed.

The *Monitor-Analyze-Ac (M-An-Ac)* and *Monitor-Analyze-Predict-Act (M-An-P-Ac)* instances are considered autonomic loops once there is no visualization response and the system is able to make decisions automatically. Similarly to the supervised instances, prediction is the difference between the autonomic instances. The lack of human intervention raises integrity and security concerns which must be taken into account during the conception of the solution. In order to implement these instances the system must be able to analyze the ripple effect of the decisions to be made in advance.

4.3. Example of Classification

In order to illustrate the use of the classification system, we categorize smart city projects in this section. These projects have been: (i) developed by the players introduced in Section 3.1 or (ii) involved in the cases presented in Section 3.2. For each classified project, the characteristics of its processes are discussed.

Monitor-Visualize-Act (M-V-Ac) The *IT Communications and video surveillance in Amsterdam* project can be classified in the M-V-Ac category of our classification system. This project comprehends the ***monitoring*** of the city by capturing real time video images from cameras. Then, this data is sent to and ***visualized*** in a centralized operations center, allowing agents (e.g. operators) to ***act*** upon events identified on the images.

Another example of smart city project that falls into this category is the *Smart parking in Santander*. In this project, there are close to 400 sensors (monitors) installed on parking lots around the city. The sensors automatically detect the variation of the magnetic field generated by a car parked on it - i.e. ***monitor*** *poll mode*. The information gathered by the sensors is sent periodically to the repeaters and then to a central server. The server is in charge of storing and updating the information. There are a series of panels located within the city of Santander to ***visualize*** the number of free parking slots. This information is updated every 5 minutes to allow the citizens to ***act*** more precisely – i.e. find a free parking spot in the shortest time.

Monitor-Analyze-Visualize-Act (M-An-V-Ac) Regarding the M-An-V-Ac category, we can mention the *Bus fleet management system and traffic prioritization* project in *London*. In this project, onboard computers were installed in around 8000 buses for mainly location ***monitoring*** in real-time and data/voice radio communication. Computers were also installed in bus stops and garages. The data collected coming from these computers is sent to a control center operations and then, ***analyzed*** to produce the estimated arrival time on the bus stops. This information can be ***visualized*** by passengers inside and outside the bus, allowing them to plan their trips more precisely. The project also included the installation of computers in around 1500 traffic lights, allowing operators in the control center to ***act*** upon the traffic lights – e.g. provide priorities to buses by setting green light and, therefore, make up time.

The *Amsterdan's Smart Meters* project is part of the Amsterdam case presented in Section 3.2. In this project around 500 Amsterdam householders were equipped with smart metering systems. They automatically ***monitor*** the energy consumption in real time and send the monitored data to a centralized portal. In this portal the data is ***analyzed***, generating useful information for the citizens. By accessing that portal, citizens can check or ***visualize*** online how much energy they are using and what steps need to be taken to reduce consumption. In other words, by doing so, citizens can ***act*** to save on energy costs and eventually help bring about a reduction in CO_2 emissions.

Monitor-Analyze-Predict-Visualize-Act (M-An-P-V-Ac) The weather forecast project in the context of the *Rio's Operation Center* falls in the M-An-P-V-Ac category. In this project, the weather radar is responsible for ***monitoring*** a 250 kilometer area around the city – i.e. automatic process in the monitor poll mode. This data is then processed and ***analyzed*** in the Operations Center. The processed data is used as input for a weather prediction model that produces weather ***forecasts*** for the next 48 hours. All the information is ***visualized*** internally at the Operation Center and only the relevant one is broadcasted to citizens. The visualized information is essential to ***support decisions*** regarding upcoming weather related events. This information also facilitates ***act*** immediately, without counting on the prediction process. Whenever rainfall reaches 40mm in an hour, sirens wail and text messages are sent to trained community leaders.

Monitor-Analyze-Act (M-An-Ac) Regarding autonomic projects, we can mention the *Automatic train protection system in Italy*. In this project the train is almost controlled in automate manner. The system only requires the driver to acknowledge any change in the aspect of the next signal. It continuously ***monitors*** the train speed and computes braking curves. The wheel velocities are calculated by ***analyzing*** numerical derivatives starting from the impulse counters and the defined speed limit for the road. Then, the system decides whether and how to ***act***. An alarm is sounded in the cab if the train exceeds a defined speed limit. If the train exceeds the speed limit by more than a given threshold or misses the designated stopping place, the system applies emergency brakes. Note that there is no visualization involved on this activity since the system is autonomous to decide when to act or not.

Monitor-Analyze-Predict-Act (M-An-P-Ac) Although this work is by no means exhaustive, there were no examples of autonomic cycles with prediction (M-An-P-Ac) within the researched projects. There is only one autonomic initiative. This is neither a limitation of our classification system nor necessarily a problem, once automation cannot always be considered as an evolution of the process. The level of automation and adoption of technology might be positive in some cases but not desired in other regions where, for instance, cultural aspects may suggest city processes must have human intervention to be considered safe.

5. Conclusion

This paper proposed a framework composed of five processes: Monitor, Analyze, Predict, Visualize and Act. The framework has been conceptually described. First, the processes that compose the framework have been depicted, then it has been instantiated, and lastly, some smart city projects have been classified. The proposed classification does not imply that the more processes a project contains, the better it is. It is only an instrument to categorize the smart cities projects according to their characteristics.

It was possible to observe that the number of autonomous projects is limited compared to non-autonomous ones. We suspect that this is probably due to cultural barriers. As technology mature and other projects showcase the evolution of it, the trend is that autonomous projects increase their proportion in the smart city universe. We also observed that to make a city smart, it is required an articulated initiative where the city government, citizens, research centers and private companies cooperate. The idea behind this cooperation is to achieve more effectively the goals of improving citizens' quality of life, developing economical sustainability, and better understanding city phenomena.

As future work, a further research on autonomous projects should be carried out in order to investigate the causes that have hindered their widespread adoption in the city domain. We also believe that elaborating a ranking for the smart city projects, considering both quantitative and qualitative aspects would represent a significant contribution to the smart city area. In terms of quantitative aspects, we could mention the total investment and the amount of savings directly allowed by a project. On the other hand, the project's maturity level and the improvement in citizens' quality of life proportionated by it could be a good qualitative indicator.

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