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**Applying Lean Thinking
to Smart Cities**

Environmental Sustainability and
Resources Waste Reduction

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Dissertation presented as partial requirement for obtaining
the Master's degree in Information Management

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by

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DEDICATION

Dedico este trabalho à Maria João e ao Horácio, que sempre acreditaram em mim mesmo quando eu não acreditava.

À Márcia, por ser um porto de abrigo (em sentido figurado e, também, no sentido literal).

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ABSTRACT

Inequality in population distribution between urban and rural areas tends to increase in the next years, in favor of cities, and the trend is not expected to revert (United Nations, 2014). Therefore, cities should be eager to receive their share of inhabitants, seeking to host within their borders the optimal number of people needed to self-development and thrive.

At the same time, urban areas must be prepared to offer citizens the services matching their expectations, in fields such as education, healthcare, transportation, water and energy supply. More people demanding for more services requires either a higher need of resources or a better utilization of the available ones. In a context of economic adjustments, the second option is normally the most viable.

The concept of Smart City is brought to discussion as a city that, with the support of Information and Communication Technologies (ICT), creates a system that progressively facilitates its own functioning, becoming more intelligent, interconnected and sustainable (Debnath et al., 2014). Nowadays, technology allows people to send and receive data in real-time, with this data acting as a supporter for quicker and fact-based decisions, granting us the possibility of saving precious resources, as time or capital.

Resource efficiency is one of Lean Thinking potentialities. This line of thought is used within organizational context to, among other applications, identify activities embedded in business process that do not add value to the final product or service. In this investigation work, it is proposed to apply Lean Thinking in the development of an integrated administration system for a city, within the Smart Cities paradigm, to allow urban managers to take advantage of Information and Communication Technologies (ICT) for a better utilization of resources, minimizing waste of the available reserves.

KEYWORDS

Lean; resources; waste; Smart City; sustainability

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LIST OF ABBREVIATIONS AND ACRONYMS

CCU	Command and Control Unit
CEP	Circular Economy Portugal
DSR	Design Science Research
FIFO	First In, First Out
GPS	Global Positioning System
ICT	Information and Communication Technologies
JiT	Just in Time
LED	Light-Emitting Diode
VSM	Value Stream Mapping

1. INTRODUCTION

1.1. BACKGROUND

Following the recent trend it is expected that more than half of the world population will live in cities until 2050, with the number becoming more expressive if only considered the most developed regions of the earth (United Nations, 2014). Therefore, it is up to the cities to ensure they are (or they become) sufficiently attractive to guarantee their share of the future urban population.

The higher the ability of a city to attract people to live, work, study or visit, the higher its development potential and level of competitiveness when compared to other cities. For that to happen, it is fundamental that the city meets the needs of its inhabitants, workers, students, and tourists, in several domains such as, for example, mobility, education, or security. However, increasing the attractiveness of a city, and the consequent population growth, presents the challenge of hosting a higher number of consumers of resources such as water, electricity, housing, healthcare, or solid waste treatment. Cities and their governments can opt for (i) increasing the level of resources used or (ii) increasing the efficiency of the current resources. In a context of public expenditure reduction, the second option presents itself as the better one.

The concept of Smart City comes in as the city which can conjugate the two sides of the same coin, a city able to attract individuals while managing the available resources efficiently, able to promote economic and social development taking into account environmental conservation, able to satisfy its citizens' needs in a sustainable way (Castro Neto et al., 2017). This is only possible if cities provide their researchers and citizens tools to stimulate the needed creativity in the development of solutions to sustain these premises. A way of leveraging the creation of solutions for Smart Cities is real-time data sensing, transmission and analysis, supporting the optimization of several processes composing the function of the urban ecosystem.

Efficient resources management and process optimization are also attributes of Lean Thinking. With its origins in the post-World War II, within the Japanese automobile industry, and more specifically in Toyota Motor Company, this management paradigm was developed in a scarcity context, having to focus on efficient resource utilization. Lean Thinking also advocates a great proximity between managers and field workers, in a way to quickly identify and mitigate problems in the front line. With the results obtained in Toyota, other automotive companies have adopted the strategy; with proper adaptations, other industries have embraced it as well.

This research intends to bring together these two realities, suggesting a framework within the Smart Cities paradigm and after reviewing its fields of action, based on the Lean Thinking methodology. This framework will be presented to relevant specialists, so it can be validated and criticized, to obtain conclusions regarding the utility of Lean Thinking in managing a Smart City.

1.2. MOTIVATION

The Smart Cities subject aggregates an increasingly number of enthusiasts and specialists, becoming a growing topic among researchers. According to ScienceDirect, a publications repository, the first reference to the exact expressions "smart city" or "smart cities" dates to 1996, remaining meaningless

until the early 2010s: since then, the number of publications as grown at a level than, in average, more than duplicates the records of the previous year.

Figure 1 Evolution of the number of publications with the expressions "smart city" or "smart cities", according to ScienceDirect (as of 2017/11/20)

Being a relatively new paradigm, it still lacks structure and organization in the way its solutions development processes are systematized. Lean Thinking has been used in this context within organizational environment, not only structuring processes but also implementing a continuous improvement framework, revisiting the processes from time to time. It is, therefore, a methodology that may help the operationalization of a Smart City, while aiming to improve the current solutions or the development of new ones.

1.3. OBJECTIVES

The main objective of this research work is to propose a framework to apply Lean Thinking to city management, to contribute for the Smart City desideratum. To achieve the main objective, it is fundamental to satisfy the following intermediate objectives:

- Analyzing what Lean Thinking represents nowadays;
- Analyzing and defining the Smart City concept;
- Developing a Lean Thinking framework within the Smart City concept;
- Validating the framework with a set of relevant specialists and;
- Draw the appropriate conclusions regarding the utility of Lean Thinking applied to Smart Cities.

2. LITERATURE REVIEW

2.1. LEAN THINKING

2.1.1. Historical background

Lean Thinking arises in Japan's restructuring context post-World War II. The need to reform the way of producing in Toyota Motor Company (established in 1937 – two years before the beginning of the war) took Eiji Toyoda, Toyota's production engineer, to visit Ford's factory in Detroit in 1950, in the peak of mass production. The initial idea of applying Ford's production principles to Toyota, however, fell apart after several attempts from Toyoda and Taiichi Ono, an industrial engineer, to implement the system in the Japanese automobile manufacturing company (Womack et al., 1990); it is relevant to briefly revise mass production to understand why.

2.1.1.1. Rise and fall of mass production

Mass production, launched by Henry Ford in 1913 in the automobile industry, was characterized by:

- One-way fit pieces and ease of parts replacement (by standardized production);
- Easy replacement of workers, with the division of work into elementary tasks (contrasting with specialized work in craft production, demanding highly qualified workers);
- Introduction of the assembly line, with workers assuming a static position in the factory performing only one task;
- Introduction of the industrial engineer, to absorb the tasks around the vehicle manufacturing (pick up tools and parts, defective parts repair, quality control and final product delivery);
- Introduction of the quality inspector, to detect defects reported to a created rework team to correct;
- Introduction of the foreman, to detect interruptions in the assembly line;
- Decision making concentrated in the top manager.

Henry Ford structured his factories to produce only one type of automobile – the Model T in Detroit (USA) until replaced by the Model A in 1927, and the Model Y and Ford V8 in Dagenham (England) and Cologne (Germany) respectively, in 1931. Raw material entered by one of the factory gates and was processed until the final product was ready, leaving the factory by the other gate and eliminating external intervention.

The elementary division of tasks allowed the recruitment of poorly qualified workers for the assembly line, creating at the same time new indirect workplaces for knowledge workers, manipulating ideas and information never touching a single automobile part. Line workers had a single task having very plain but stressful jobs, resulting in high turnover level but becoming easily replaceable, specially by recently arrived immigrants who were not able to speak English and were willing to accept sub-optimal work conditions.

Ford achieved productivity levels never reached before, allowing him to raise salaries and decrease prices. This contributed to a reduction of turnover, keeping workers in the same company and job position for a longer time. Naturally, the workers stress was raising, motivation and expectations were falling, and negotiations between workers and employers were centered in work time reduction (Womack et al., 1990).

2.1.1.2. Lean Thinking origin

The Japanese economy was, at that time, devastated by World War II and, as such, the country's industry lacked financial structure to acquire the technology needed to implement mass production. Furthermore, the economy of the country was focusing essentially the internal marketing, implying for the automobile industry the production of a large variety of vehicles in small quantities.

Japanese workforce was composed by natives, not willing to accept being treated as disposable pieces of the production process. The dismissal right was highly restrictive, raising the negotiation power of the workers and not allowing the turnover levels of mass production.

During his visits to Ford's factory in Detroit, Ohno identified aspects of mass production which caught his attention:

- The system contained several waste spots regarding effort, time and raw materials;
- None of the indirect workers added effective value to the final product;
- The front-line worker had the lower status within the factory, being frequently told that he was only necessary until his task could be automatized; Ohno saw in the front-line workers potential to replace indirect workers, as their contact with the production process was continuous conceding them a higher knowledge about it.

Based on these findings, Ohno began a set of experiments that would lead to Lean Thinking.

2.1.2. Lean Thinking main aspects and characteristics

Lean Thinking is often associated with the simplistic expression "doing more with less" (Stone, 2012). Liker (1996) formulated a definition that served as a basis for several authors, attributing to Lean Thinking the category of a philosophy which, when implemented, decreases the total time between client request and delivery, eliminating waste throughout the process. Karim & Arif-Uz-Zaman (2013) refer to Lean Thinking as the set of activities that minimize organizational waste, improving value added activities.

2.1.2.1. Lean Thinking principles

Womack & Jones (1996) established in their book, *Lean Thinking*, the five aspects they consider to be the main principles of the methodology:

- Value identification – it is crucial to identify value, expressed in terms of a specific product or service, and from the client's point of view; providing the client a product or service he doesn't want, or need, is considered waste;

- Value-chain identification – determining all the activities composing the production process gives visibility to value added, non-value added (but inevitable) and waste activities. It is then possible to remove all waste activities, rethink the need for non-value added activities and refine value added ones;
- Flow – when all waste is eliminated, the remaining activities must be organized in a way to avoid interruptions, delays or bottlenecks;
- Pull – with clear value definition, and with a flowing value-chain free of waste, time from beginning of production until delivery decreases. Thereby, it is the customer pulling the product or service, instead of the organization pushing it;
- Perfection – the fifth and last principle consists in the continuous application of the previous four: continuously looking for waste, redefinition of value, and repeated perfection of value-chain activities – *kaizen*, the Japanese word frequently found in Lean Thinking literature.

2.1.2.2. Value and waste

Stone (2012) defines “value” as an added capacity provided to the client, at the right time and the right price, considering his point of view. His research also presents a definition for “waste” as all activities embedded in the processes of an organization absorbing resources without adding value; a set of authors, like Bhasin & Burcher (2005), acknowledge the existence of seven types of waste:

- Overproduction - production in quantities above the necessary;
- Waiting – time on hold of a resource;
- Transportation – carrying objects unnecessarily;
- Overprocessing – work not requested or above demanded quality;
- Inventory – unfinished products or products in need of storage;
- Motion – unnecessary movement of people;
- Defects – rework done due to errors.

2.1.2.3. Lean Thinking tools

A set of tools is used to maximize value and eliminate waste. Some of the tools are presented next:

- a) Value Stream Mapping (VSM): a visual representation of the value chain; this representation allows the value chain to be analyzed and discussed, in particular activities to improve or eliminate. For VSM to work, Schmidtke et al. (2014) define a four phase procedure:
 - i) Select the product, or product family, to approach;
 - ii) Represent the current flow;
 - iii) Redefine the flow to have the future state;
 - iv) Plan the implementation of the future state.

- b) *Heijunka* (leveling): a tool to mitigate the impact of high and low demand seasons. Consists in granting stability to the production system, defining the amount to produce through time (Grimaud et al., 2014). Methods (such as exponential smoothing) are used based in demand history or seasonality, resulting in a forecast of the future demand. The stability of the production shields the value chain from abrupt changes in demand, reducing stress among workers; in addition, production during low demand seasons may meet the needs of high season demand (Grimaud et al., 2014).

Figure 2 Example – Real demand (solid line, grey) vs. Production level (dashed line, green)

- c) Just-in-Time (JiT): a philosophy that determines that an activity of a process only executes work that can be absorbed by the next one (Ohno, 1988). Therefore, waste such as waiting, overproduction or inventory is avoided. This improvement results from the integration of clients and suppliers in the production process (Kannan & Tan, 2005), shown in Figure 3.

i)

ii)

Figure 3 Conventional production (i) vs. JiT production (ii)

- d) Error prevention (*Poka-Yoke*): techniques used in production processes to avoid defects in the final product, resulting from mistakes during the process (Vinod et al., 2015). These techniques consist in physical devices (blocking flow of mass, energy or information), functional devices (turned on or off through, for example, a password, depending therefore from user interpretation), or symbolic devices (physically present, but requiring interpretation – for example, a warning sign) (Saurin et al. 2012).

2.2. SMART CITIES

2.2.1. Historical background

Populations tend to concentrate in urban areas: in the most developed areas of the world it is expected an increase from 54,6% in 1950 to 85,4% in 2015 – an absolute increment of 30,8% in a hundred years (United Nations, 2014).

Figure 4 Percentage of urban population in the most developed áreas of the world (Europe, North America, Australia/New Zealand and Japan), 1950-2050 (United Nations, 2014)

However, urban growth results in social, economic and organizational issues to the cities as, for example, an increase in traffic, pollution or social inequality (Kim & Han, 2012) . These issues, if not addressed properly, may jeopardize economic and environmental sustainability of the cities; the Smart City concept arises as an answer to this trend, as the paradigm for evolution, development and sustainable growth of current cities. The Smart Cities approach seeks to find solutions for planning, livingness, viability and sustainability of urban areas, via technological evolution (Neirotti et al., 2014).

The term “Smart Cities” may have had its origin in the Smart Growth Movement, in the late 1990s, which advocated new urban planning politics. Subsequently, technological companies adopted the expression to define the information systems integration within urban infrastructures and services, such as buildings, transportation, or water and electric supply. Today, the term covers mainly any technological innovation contributing for planning, developing and operationalization of urban infrastructures or services (Harrison & Donnelly, 2011).

2.2.2. Smart Cities main aspects and characteristics

Despite the diversity of definitions, a Smart City is, for Debnath et al. (2014), an urban system using the Information and Communication Technologies (ICT) infrastructures as a way to facilitate its operation, becoming progressively more intelligent, interconnected and sustainable; for Neirotti et al. (2014), a Smart City is a system collecting a large amount of data in real-time, processing it and acting on itself for self-optimization; Deloitte (2015) considers a city as smart when investments in human and social capital, legacy infrastructures and disruptive technologies support its sustainable economic growth and high living standards, with a wise management of natural resources and a participatory governance.

2.2.2.1. Smart Cities as a smart system

The conceptual idea around a smart system is that it is self-operational, reducing or eliminating human intervention. Smart systems are supported by smart technologies, characterized by three elements (Debnath et al., 2014):

- a) Sensors, to collect data about the current state of the system;
- b) Command and control unit (CCU), to process data and decision-making;
- c) Actuators, to execute decisions.

To be considered smart, a system must work in a collect-process-act closed cycle, mediated by an effective communication network (as shown in Figure 5). However, an advanced level of smartness can be added to these three features, by adding prediction (the capacity to predict eventual problems), repair (the capacity to fix problems) and prevention (the capacity to predict eventual problems and to take preventive measures to avoid or minimize its effects), as shown in Figure 5.

Figure 5 Smart systems cycle, adapted from Debnath et al. (2014)

Figure 6 Smart systems features, adapted from Debnath et al. (2014)

2.2.2.2. ICT contribution

ICT have a central role in Smart Cities operation. The massive collection of real-time data about a Smart City is only possible using suitable technology.

The use of ICT in an urban context has a similar application as to other organizations, such as (but not limited to) process automation, data collection and analysis, decision-making support, planning and control (Neirotti et al., 2014).

2.2.2.3. Fields of action in a Smart City

Neirotti et al. (2014) distinguish two types of fields of action in a Smart City: the tangible domains (where ICT plays an important role) and the intangible domains (where ICT plays a more limited role). Table 1 shows a summary of the considered fields of action and their main objectives.

Domain	Main objectives
Tangible domains	
Energy grid	Effective energy provision, exchange of information regarding electricity consumption
Street lighting	Street lighting network effective management
Water management	Measurement of water consumption and leakage
Solid waste management	Definition of solid waste collection flow, destruction and recycling of solid waste
Natural environment	Usage of technology for environmental resources protection, pollution control
Transportation and mobility	Optimization of transportation networks considering traffic and energy consumption, real-time provision of traffic information
Buildings	Adoption of technology to create “living” buildings
Healthcare	Technology usage in remote assisted healthcare, diseases prevention and diagnose
Security	Real-time data transmission to security forces
Intangible domains	
Education and culture	Utilization of ICT tools in educational institutions, promotion of cultural events in online platforms
Social inclusion	Development of tools to decrease social barriers
Public administration and e-government	Development of online public services, electronic voting, shared governance
Economy	Promotion of innovation, entrepreneurship, the integration of the city in global markets, of circular economy models

Table 1 Smart Cities fields of action

Below are presented some projects, models or final solutions regarding the mentioned domains.

Energy Grid

A smart electric grid is a network that includes sensors throughout the whole structure, to collect several indicators such as power, voltage or failures at specific key points (Feng et al., 2016). This network results of the addition of two layers to the traditional system: a data collection and transmission layer, and a data analysis layer. The information obtained may be disclosed (i) to allow automation of the system; (ii) to power companies granting them the possibility of, for example, quick detection of failures; (iii) to consumers to concede them the access to their consumption data, so they can improve their energy usage patterns and increase energy saving (Yan et al., 2013).

Electric Power Research Institute estimates a decrease of 1.294 to 2.028 billion dollars in energy costs, and a reduction between 5 to 9% of greenhouse gas emissions, with the implementation of smart energy grids (EPRI, 2011).

Street lighting

When effectively used, public lighting is an essential instrument in urban life, considering its contribution to a decrease in traffic accidents, a decline in criminality, the promotion of socioeconomic night activities and an increase in the security perception of citizens (Lau et al., 2015).

A smart public lighting system adapts its lighting levels considering external factors like natural light, atmospheric conditions or traffic intensity. This adjustment can be made using sensors placed throughout the lighting network (Jagadeesh et al., 2015).

Besides, transition to light-emitting diode (LED) technology in public lighting represents less energy costs, less maintenance costs, and improved durability of lamps; according to Northeast Group LLC (2016) there were 315 million lamp posts using LED technology, with a growth trend to the 359 million until 2026.

Water management

Smart water management comprises the acquisition of data regarding water consumption, as well as water leakage responsible for the loss of about 30% of the whole water provided (Soldevila et al., 2016).

For a smart water management system to be in place, it is necessary to combine water distribution with appropriate ICT to measure water flow, pressure, leakage or contamination, in several points of the network. This data collection, along with convenient software, allows an improvement in water consumption patterns, leading to resource and economic savings (Cheong et al., 2016).

Solid waste management

Traditional waste management is based on static routes, happening at a certain date and time, coming out as inefficient as it happens the passage of vehicles by overflowing dumpsters that should have been emptied before, or almost empty ones that could have been collected later. This system uses inefficiently resources such as workforce, time and truck fuel.

Ecube Labs (Ecube Labs, 2011) and NEC (NEC, 2014) are two companies providing smart solid waste management solutions, including dumpsters able to detect their filling level, and to compress the contained waste optimizing their self-capacity. Each dumpster sends data regarding filling level to a central system, allowing analysis on waste production trends and collection-route planning. This system allows, for example, savings in human resources, fuel and cuts in greenhouse gases emission.

Natural environment

To assess the environment quality provided by a city, Citibrain provides monitoring solutions for air quality, temperature, humidity, luminosity, and noise pollution, offering an integrated solution of sensors communication with a data processing central system. With this analysis, it is possible to decide which zones of the city need intervention for these types of issues (Citibrain, 2017b).

Transportation and mobility

Smart transportation and mobility aim to reduce traffic congestion and to provide quicker, cheaper and environmental more friendly mobility solutions (Deloitte, 2015). A smart transportation system encompasses vehicles with sensors determining speed, door-opening frequency or global positioning system (GPS) devices, so it is possible to inform passengers about the vehicle's estimated time of arrival to a specific point, or future route optimization (Khan et al., 2016).

Regarding individual automobile mobility, Citibrain supplies a smart parking solution integrating sensors, placed along parking slots, with a central system collecting data about the occupation of each slot. The set of empty slots is transmitted to interested drivers, reducing not only slow driving to the parker and other cars but also reducing fuel waste and greenhouse gas emissions (Citibrain, 2017a).

Buildings

A smart building is a facility with the needed features to measure, monitor, control and optimization of its operations and maintenance. Some of the objectives of a smart building are the reduction of greenhouse gas emissions, increase in energy savings, maintenance resources optimization, and improvement in prediction of energy and resources used, increasing in addition the value of the building (Wipro, 2016).

Intel provides solutions including interior parking sensors to retrieve information about vacant slots, humidity sensors to identify if green areas of the building need irrigation, biometric sensors to restrict the access to certain areas, a mobile app including the building plant or information about the place of next meetings, or presence detectors to adapt automatically the temperature and luminosity of the rooms (also regulated via mobile app). These features ensure a better experience to users as well as an increase of resources efficiency (Intel, 2017).

Healthcare

Smart healthcare includes key health parameters measuring (through, for example, wearable devices) that can be used in a preventive or monitoring way. By frequent monitoring and prevention, it is possible to reduce the affluence to healthcare infrastructures and the overload of the healthcare system.

Intellicare (2017) provides a solution integrating sensors (weighting scales and blood sugar and pressure) with a central system, to create a database for trend analysis. This data is available to healthcare professionals and trigger alerts in case of diverted measurements, so action is quicker and more effective.

The same company provides solutions for elderly people, an increasing segment of the population. One of the solutions consists in a small device, carried in the pocket or the waist, that allows an emergency telephone call by pressing only one button. The device is also equipped with global positioning system (GPS) technology, so families and caregivers can know the location of the user. This solution increases not only the quality of life of the elder but also the quality of life of the family.

Security

An increase of the urban population requires a more efficient use of security forces for a real-time action. An example is Rio de Janeiro Operations Center, a building to control urban operations of the city working non-stop to assure its normality, by preventing events compromising the safety of the citizens, and for quick action in case of unexpected events. This system is supported by sensors and cameras distributed along the city, collecting data to be analyzed in the central building supporting decision-making. Inside the building there is also a meeting room equipped with videoconference technology, to be possible to contact the mayor in case of crisis (Centro de Operações Prefeitura do Rio, 2017).

Figure 7 Command and control room (Centro de Operações Prefeitura do Rio, 2017)

Education and culture

The educative offer of a city is a pull factor for new citizens and retention of the existing ones, becoming key to enhance knowledge workers' skills development, and entrepreneurship.

For an effective answer in an increase of demand for educational services, universities and schools enjoy access to ICT solutions allowing, for example, electronic enrollment for students, or the creation of digital communication channels. These solutions improve the educational services, as they reduce waiting time and congestion, remove paper services and its risk of loss, and increase the speed of access to relevant information (Dirks et al., 2010).

Social inclusion

Progressive digitalization of urban environment and most of all daily life parameters compromises the integration of citizens with restricted access to technology, and a smart city must ensure these citizens are not left out.

Eurocities (2014) gathered in a study some digital-inclusion initiatives:

- “Digikriebels” project, providing access to ICT to children from disadvantaged families, as well as education to relatives so they can keep track of the child’s development;
- “A society in which I am learning and feeling good” project, consisting in ICT training sessions to elderly people;

- The Sheffield Community Network, with the objective of developing technological skills of Sheffield citizens, a highly industrialized city whose population suffers the effects of the industry decline.

Public administration and e-government

Development of online public services, such as tax return, is crucial in a demographic growth context to provide citizens a better service. This way it is possible to avoid travelling to governmental buildings decreasing their congestion.

Participative democracy increases the level of citizens engagement in local governments decisions. These initiatives are found in Portugal at several levels:

- National level, as for example Orçamento Participativo Portugal (OPP, 2016);
- Municipal level, as for example Lisboa Participa (CML, 2017);
- Local level, as for example Orçamento Participativo de Avenidas Novas (JF Avenidas Novas, 2017).

Economy

Circular Economy concept is often associated with Smart Cities as a sustainable way of wealth creation. This economic model is opposed to Linear Economy, the conversion of natural resources into waste, via production and consumption. However, the current use of natural resources is above the sustainable level: Global Footprint Network (2017) estimates a current 170% consumption level of the total available resources of the planet.

Figure 8 From Linear Economy to Circular Economy, adapted from Circular Economy Portugal (2017)

In the transition from Linear Economy to Circular Economy, recycling plays a key role, providing part of the total resources needed for production; nevertheless, the other part of the resources still comes from extraction, and not all the waste is reused.

The Circular Economy model requires all the resources used in the creation of new products to come from end-of-life products, meaning the reuse of all the waste and the end of new raw material extraction. Waste derived from production and consumption processes is also incorporated in a new production process.

In Portugal, Circular Economy Portugal (CEP) supports initiatives for citizens (for example, Repair Café Lisbon – free events where citizens take and repair old objects with the help of skilled professionals and volunteers) and companies, supporting the transition into the Circular Economy model (Circular Economy Portugal, 2017).

3. METHODOLOGY

3.1. DESIGN SCIENCE RESEARCH

The option for Design Science Research (DSR) was due to the fact that it is an adequate methodology for the production of artifacts resulting from an informed and conceptual way of thinking. According to Vaishnavi & Kuechler (2015) DSR encompasses five main stages:

- Awareness: perception of the problem, from which a study proposal derives;
- Suggestion: creative phase of the process, from which possible solutions to the problem arise, based on new or existing elements;
- Development: proposed solutions from the previous phase are developed and final versions of the artifacts to present are created;
- Evaluation: developed artifacts are evaluated, coming out as appropriate or not to solve the problem;
- Conclusion: also known as the reflection phase, where results from evaluation are published, contributing to knowledge and triggering new studies.

Figure 9 DSR model (Vaishnavi & Kuechler, 2015)

Although the artifact to build is not physical, but a framework, DSR is also adequate since it allows an informed awareness about Lean Thinking and Smart Cities, leading to the preparation of the model.

3.2. RESEARCH STRATEGY

The five DSR phases applied to the present research are structured as follows:

Figure 10 DSR stages applied to the present research

The awareness stage consisted in an analysis of the Smart Cities paradigm, namely its origin, main features and existing solutions; and the Lean Thinking methodology, its roots and main organizational contributions.

Afterwards, in the suggestion phase, the framework structure was designed, resulting in the option for a matrix linking fields of action in a Smart City with the types of waste considered in Lean Thinking.

The development of the framework consisted in the creation of proposals to implement in Smart Cities, contributing to the elimination of resources waste.

With the framework created, the evaluation phase was carried out conducting individual interviews with three relevant experts.

Ultimately, the results of the interviews were discussed, and the proper conclusions were drawn.

4. LEAN FRAMEWORK FOR SMART CITIES

Considering the literature review regarding Lean Thinking and Smart Cities it was possible to develop the framework included in this chapter.

Lean Thinking, as an optimization methodology, can be built-in into Smart Cities as a way to:

- Decrease costs;
- Decrease resources need;
- Decrease delivery time of services;
- Increase quality of services.

4.1. FRAMEWORK PROPOSAL

The proposed framework focuses in waste reduction in the urban processes. The elimination of waste aims an increase of value in two domains:

- By increasing the perceived quality of life of citizens, receiving more and better services, cheaper and quicker than before;
- By decreasing the resources needed by governments to provide these services, making these organizations more efficient and sustainable.

4.2. RECOMMENDATIONS AND POLITICS

The presented proposals are organized to link Smart Cities fields of action (represented by letter along the lines of Table 2) with Lean Thinking types of waste (represented by numbers along the columns of Table 2):

	1. Overproduction	2. Waiting	3. Transportation	4. Overprocessing	5. Inventory	6. Motion	7. Defects
A. Energy grid	A-15		A-3		A-15		A-7
B. Street lighting	BI-1						
C. Water management			C-3				C-7
D. Solid waste management	DM-1			D-46		D-46	
E. Natural environment	E-1			E-4		EF-6 / EG-6	
F. Transportation and mobility		FI-2				EF-6 / F-6	
G. Buildings	G-1					EG-6	
H. Healthcare		H-26				H-26	
I. Security	BI-1	FI-2					
J. Education and culture		J-2 / J-246		J-246		J-246	
K. Social inclusion							K-7
L. Public administration and e-government		L-26	L-37			L-26	L-37
M. Economy	DM-1 / M-1						

Table 2 Proposals organization

4.2.1. Smart energy grid planning and management

Example: A-15 – utilization of technology to adjust the production and storage of electric energy

To be efficient, an energy grid should seek to produce the optimal quantity of electric energy. Overproduction of energy means a waste of resources, since part of this energy is dissipated; furthermore, the non-distributed energy implies its storage, using infrastructures meaning costs.

A way to circumvent this problem is to develop a system encompassing data collection sensors throughout the network, and adequate data analysis software, to predict the urban needs of energy and adequate the production according to the forecast.

This recommendation intends to decrease the overproduction (1) and inventory (5) of electrical energy (A).

Example: A-3 – least-effort principle applied to energy grid

A Smart Cities manager should require the planning of the electrical grid so that, amongst other indicators, the energy loss rate is as low as possible. This loss may happen, for example, due to the transformation of electric energy into thermal energy throughout the network.

A contribution to a decrease of this loss rate may be the redefinition of the distribution network (or the initial definition, in case it is to be applied to a city constructed from scratch) so the energy is transported through the shortest possible path.

With this principle in mind, electrical energy (A) transportation (3) decreases, diminishing energy loss.

Example: A-7 – detection of failures in the energy grid

A simple failure in the energy network may jeopardize the operation of, for example, houses, public and economic infrastructures, transportation means or street lighting.

To avoid the constraints caused by electric supply failures, it is suggested the introduction of failure detection sensors throughout the network, sending data to a central system that triggers alerts for quick detection of failures, so the appointing authorities can intervene faster.

This proposal it is intended to provide a better electrical supply service (A) reducing the impact of the network's defects (7).

4.2.2. Smart street lighting planning and management

Example BI-1 – Motion sensor for people and vehicles

Motion sensors placement throughout the paths with lighting needs, adjusting the light intensity along the way, enables the optimization of lighting production. This proposal has an impact in the decrease of public lighting (B) costs, avoiding the overproduction (1) of light (and subsequent energy expense) to supply the service.

Sustainable public lighting also increases the level of security (I) perceived by the citizen, helping to avoid phenomena such as robbery, pickpocketing or carjacking.

4.2.3. Smart water supply management

Example: C-3 – least-effort principle applied to water supply

Water leakage is one of the biggest concerns for water management entities; as seen previously, it is estimated that 30% of the water provided is not billed. A Smart City manager may want to redefine the distribution network (or plan it, in case it is to be applied to a city constructed from scratch) so the water flow path is the shortest possible, reducing the potential spots where water leakage may occur.

This measure reduces the transportation (3) of piped water (C), reducing consequently the leaked volume.

Example: C-7 – water leakage detection

Another measure to decrease the lost water volume is the real-time detection of leakage spots. The quicker the leakage is detected, the smaller is the impact.

It is proposed the introduction of sensors throughout the network, sending data to a central system that triggers alerts when leakages are detected. This measure intends to reduce the impacts of defects (7) in the water supply network (C), complementing the previous one: if it is not possible to reduce the whole number of water leakages, it is at least possible to decrease their impacts.

4.2.4. Smart solid waste management

Example: DM-1 – limitation to non-recyclable waste deposit

Solid waste, when properly separated, is a factor with influence in the environment and economic fields, not ending in a landfill and being reused as primary material in production processes. A way to increase the waste separation rate is to limit the quantity of non-recyclable waste produced.

This proposal suggests the implementation of small annexes in residential zones, where dumpsters are placed, with access via electronic key to identify the depositor. Within the annex, the citizen may deposit an unlimited quantity of recyclable waste, but a limited quantity of non-recyclable waste. Dumpsters must be equipped with proper technology to assess the material of the waste deposited.

This proposal aims to encourage the separation of solid waste, reducing overproduction (1) of non-recyclable waste, with impact in solid waste management (D) and economic agents (M).

Example: D-46 – dumpster filling level sensing

Introduction of filling level sensors in dumpster, to assess in real-time their filling level, is a help to define the best route to collect only dumpsters that have reached a level pre-defined as optimal. An illustration of the concept is shown in Figure 11.

Figure 11 Example of optimized waste collection route; standard route (black outline), optimized route (blue outline), minimum level for collection (70%)

This proposal aims to minimize the performed work (4) by the solid waste (D) collection team, and the travelled distance (6) of the team and garbage trucks, meaning savings with personnel and vehicles wear-and-tear and fuel.

4.2.5. Natural environment improvements and natural resources saving

Example: E-1 – pollution levels sensing

Population concentration within the urban areas naturally increases the levels of pollution; two examples are noise and air pollution.

This proposal suggests the implementation of atmospheric and noise pollution sensors to assess which zones of the city are more affected by these disturbances. After data analysis, it will be easier to the appointed authorities to define priorities regarding intervention areas.

With this measure, it is intended to eliminate the overproduction (1) of noise and air pollution, harmful to the natural environment (E).

Example: E-4 – humidity sensors for green areas

Green areas are essential to the urban environment, not only as socializing and leisure areas, but also for oxygen production. However, these spaces have water needs that may be addressed via irrigation or rainfalls.

This proposal suggests the introduction of humidity sensors in green areas with water needs, to assess the humidity levels of the area. The irrigation system will work if the humidity levels low, due to the lack of rain, and will not work if humidity levels are enough to satisfy the water needs.

The implemented system aims to avoid the overprocessing (4) of irrigation, saving natural resources (E).

Example: EF-6 – least-effort principle applied to urban roads

The urban roads network is essential for a fluid motion of people and goods within the city. Smart City's routes should privilege not only the shortest path between two important points of the city, but also the priority to public transportation, motorcycles, electric vehicles and other transportation means less harmful to the environment.

If, by defining the terrestrial roads, a Smart City manager has these points into account, the vehicles' (F) motion (6) decreases implying a reduction of costs, and a lower emission of greenhouse gases with impact in the natural environment (E).

4.2.6. Road traffic optimization

Example: FI-2 – smart traffic lights

In a traditional traffic lights system lights turn green alternately. This system is particularly inefficient in times of the day when traffic is low, as most of the times there are no vehicles in all the ways.

The proposed system, illustrated in Figure 12, is based in the FIFO (first in, first out) organization method, with the necessary adaptations to a secure vehicle circulation:

- a) No vehicles: traffic lights are red in all the ways;
- b) With vehicles in only one way: traffic light turns green in the way where vehicles are present;

- c) With vehicles in two or more ways: traffic light turns green in the way where the first vehicle is detected or, if the time is similar for more than one way, where more cars are detected. The light turns red in this way when:
- All the vehicles of the first way go through the lights; or
 - By the end of a pre-defined time, if circulation on the first way does not stop.

Figure 12 Smart traffic lights

This proposal aims to reduce waiting (2) time due to the need for traffic lights needed for vehicle mobility (F), impacting also the field of security (I) by decreasing, for example, the occurrence of phenomena such as carjacking.

Example: F-6 – smart public-parking system

The search for vacant parking slots represents time and resources spent by drivers. The driving speed decreases, not only for the driver looking for a slot, but also impacting the other drivers. This proposal suggests the placement of parking sensors in street parking slots, so the driver is able to assess the occupation rate and free slots in a certain area via, for example, a smartphone app.

This way, the driver reduces motion (6) needed in the search for a free spot, and increases the car mobility (F) for him and for drivers in the same way.

4.2.7. Smart buildings

Example: G-1 – room presence sensors

For a more efficient utilization of buildings it is necessary their real-time suitability to their users' needs. It is easy to understand that an empty room does not justify the need of, for example, lighting or acclimatization, and therefore lights or air conditioning turned on mean a waste of resources.

The placement of presence sensors within a building's room, connected with a data processing software, allows the system to automatically adapt the room to the presence of people (e.g. adjusting luminosity, turning on air conditioning or wi-fi); when the room is left behind, equipment is turned off.

This avoids the overproduction (1) of energy needed for buildings (G) commodities.

Example: G-6 – smart indoor-parking system

In occasions when a building car park is nearly full, it is useful for drivers looking for a vacant slot to know exactly where to find one, to reduce the time spent in the search.

It is suggested the placement of parking sensors, connected with a central data processing system that collects data and assesses vacant and occupied parking slots.

This information is provided to the users via, for example, a smartphone app, allowing the decrease of drivers' motion (6) within the building (G) and the emission of greenhouse gases (E).

4.2.8. Smart healthcare

Example: H-26 – healthcare remote monitoring

This proposal suggests the implementation of healthcare remote monitoring stations throughout the city, where it is possible to measure health indicators. The measurements are collected and analyzed to obtain patterns, triggering alerts in case of a measurement outside of the pattern. In that case, and when relevant, the citizen is forwarded to a healthcare center. These stations may also be implemented in retirement homes, houses of people with reduced mobility, or houses of people with need for daily measurements.

Figure 13 Healthcare remote monitoring system process

According to the results of the measurement, users can also be prioritized in an automatic way, granting a higher priority to the most urgent patient.

This proposal addresses a decrease in unnecessary travels (6) to healthcare centers (H), and therefore a reduction of the waiting time (2) for people in greater need of care.

4.2.9. Improved access to education and culture services

Example: J-2 – cultural infrastructures online guide

Monuments, concert halls and other cultural infrastructures attract tourists to the city and are also visited by residents. Naturally, there are infrastructures more requested by visitors causing waiting queues, while others are with few or no affluence.

This proposal suggests the development of visitors' redirection mechanisms as, for example, the distribution of flyers about less known infrastructures, or online guides presenting these alternatives. Municipalities can also develop an online service indicating in real-time the affluence to a certain infrastructure, so the visitor can decide better the time for a visit.

These measures aim to reduce waiting time (2) for accessing cultural infrastructures (J).

Example: J-246 – online educational services

Accessing educational services is essential for the development of urban population and the city itself, being an attraction factor of new residents. With the evolution of technology these services can become more efficient and accessible to a larger number of people.

Dematerialization of education, making it digital, allows students to experience educational services without visiting educational establishments. It is also possible to handle online bureaucratic services accessory to education services, such as enrolment submission or changes.

It is proposed these kinds of services, provided via internet, to be transversal to all the educational institutions (J), eliminating the motion (6) of students to the establishments to handle bureaucratic processes, the associated waiting time (2), and the paper files processed (4) by administrative workers.

4.2.10. Social inclusion via technological qualification

Example: K-7 – promotion of technological learning for those in greatest need

With technology present in mainly all aspects of day-to-day life, citizens in greater need face the risk of technological exclusion. This proposal suggests Smart Cities' managers to implement programs directed to these citizens granting them the access to technological equipment, as well as training sessions regarding its use, to raise as much as possible the citizens' level of familiarity with technology.

This proposal targets the social inclusion (K) of citizens in need, avoiding defects (7) in their learning process that may jeopardize the access to digital services.

4.2.11. Improve public departments' experience

Example: L-26 – online public bureaucratic services

This proposal aims the digitalization of all public services not requesting the presence of the citizen such as, for example, all paper forms. The request is made online, with the form being available instantly.

For services still requesting the presence of the citizen, it is suggested the development of electronic service tickets. The citizen can request a service ticket, or consult current the ticket and expected waiting time, via an app for smartphone.

With these measures it is expected a reduction of travels (6) and waiting time (2) in public offices (L).

Example: L-37 – interactive guide for public bureaucratic processes

This proposal suggests the development of an interactive guide, available in digital format, and containing information regarding all the documentation needed to handle public bureaucratic processes. This guide intends to centralize all the information in one single place, avoiding its replication or dispersion.

In this way, the citizen does not need to transport (3) unnecessary documents, and it is prevented the absence of other documents indispensable to the process to be handled and avoiding the initiation of a defective (7) process.

4.2.12. Boost the transition to circular economy

Example: M-1 – Incentive to the acquisition of recyclable materials

Transition from linear economy to circular economy models must be a priority, not only for Smart Cities but also for national governments. This proposal suggests these entities to gather efforts in a way to create the conditions to facilitate this transition, with, for example, incentives to the utilization of recycled materials opposed to the extraction of more raw resources. These incentives may come, for example, in the form of tax benefits.

With this proposal it is intended to reduce the overproduction (1) of natural raw materials, in favor of recycled ones that can be reused by economic agents (M) in their production processes.

4.3. VALIDATION

The framework validation process consisted in individual interviews with three relevant specialists:

- Miguel Pinto Mendes, Lean coordinator at BNP Paribas with 15 years of Lean Thinking experience;
- Jorge Máximo, city councilor in the municipality of Lisbon for 4 years, with responsibility for technology and innovation projects;
- Luis Vidigal Rosado Pereira, president of APDSI – Association for Promoting and Development of the Information Society in Portugal.

Initially, the objective of the research work was explained; afterwards, a brief reference to the two studied areas was made; lastly, three questions were asked:

- Q1: Do you think the proposed framework can be useful in Smart Cities management? Why?
- Q2: Do you think it is useful to apply Lean Thinking in managing a Smart City? Why?
- Q3: Do you have suggestions / criticism to the framework?

The collected answers are presented in the following subsections.

4.3.1. Q1: Do you think the proposed framework can be useful in Smart Cities management? Why?

Miguel Pinto Mendes

Yes, because the main source of waste is our daily life. However, it is important, in a parallel way to the strategical implementation of infrastructures and technologies to support the solutions that demand a high cost, that it is understood how is it possible to educate the citizen to use the developed solutions, and that requires a low investment. Obviously, the two realities must be integrated, as for example the parking sensors: the infrastructure is necessary, but it is complemented with the smartphone app, allowing the citizen to know where there is a vacant slot, instead of manual search;

in the solid waste case, it is essential to have the infrastructure, but also to provide the citizen the consumption or recycling indicators, creating tax benefits for recycling; in the debureaucratization of governmental structures, avoiding movement to physical locations, making services online and reducing waiting queues. This allows governments to save resources, allowing taxes to decrease.

Jorge Máximo

In a theoretical perspective the framework encompasses several reasonable proposals, coinciding with the efficiency needs of a Smart City. Although, there is a fundamental aspect that may restrain it, concerning the competences distribution and the governance responsibilities (that are asymmetric): the private entities responsibilities, the public administration responsibilities, and third-party responsibilities, making it therefore a framework that must be seen in a holistic perspective. It is necessary to consider the governance models of the institutions, because this framework will only work with articulated governance. A cost/benefit analysis has to be conducted as well, as many times these proposals demand high investment with difficult-to-assess benefits, specially while working with multi-annual short-term budgets.

Luis Vidigal Rosado Pereira

The framework is useful. Nevertheless, I would like to see highlighted what concerns private and public initiatives – municipalities, parish councils, or even public telecommunication, energy, water, sanitation or transportation operators – and what concerns individual initiatives, within the value co-production concept, arising from the citizens behavior; one example is the excessive consumption of salt or sugar: if the citizen reduces consumptions of these products, the need for treatment for heart diseases or diabetes is postponed, and the current patients suffering from these diseases have a more facilitated access to treatment.

4.3.2. Q2: Do you think it is useful to apply Lean Thinking in managing a Smart City? Why?

Miguel Pinto Mendes

If waste is the focus, then it makes total sense. For that to happen, it is necessary that cities investment projects included in local governments' plans of action have a line of thinking centered in waste reduction, seeing waste as something that consumes resources and that has a cost for everyone. This will facilitate the thinking process, because all the problems are found and addressed within a certain waste dimension, and from there the solutions to eliminate it are developed.

Jorge Máximo

Obviously. Lean Thinking may be applied to everything within governance, and clearly Smart Cities must opt for fighting everything that represents waste – otherwise they are not smart. Optimization of resources must be one of the fundamental vectors in cities management.

Luis Vidigal Rosado Pereira

As much as possible, it is an attitude to cease waste. Quality is the basis, generally speaking. And the “zero everything”: zero waste, zero papers, zero garbage. I would highlight the “time” resource: time is, for me, one of the scarcest resources, and the one we save the less; to change this, it is necessary to create a “real-time city” environment, and today that is increasingly more possible, using big data

and sensors. It is to act in real-time, and it is the time to do it, because technology nowadays allows it. Maybe we had the Lean attitude 20 years ago, but we didn't have the technology we have today. Today it is mandatory to put that attitude into practice.

4.3.3. Q3: Do you have suggestions / criticism to the framework?

Miguel Pinto Mendes

The framework seems logical as a research work, however there is a long way to run, because despite the trend shows technology is becoming cheaper throughout time, currently most of the proposed solution lay down in unfeasible technology, or only feasible in very developed countries. It should be included a prioritization matrix, to assess which of these ideas can be applied easily, with the shortest investment and the highest impact, defining them as priority. The ones requiring a large investment but considered strategical should be planned for the medium or long term. It is also essential to invest in citizens education in technological tools, so he is ready to live in an intuitive and almost automatic way. The governance structure of the city must be very well defined, understanding clearly who are the actors (central governments, municipalities, parish councils, citizens) and the role of each one. The citizen must be seen as the pillar of this structure, where everything that is being made must lay; a second layer consists in the available tools to make his life easier, as for example public services or mobile apps; in a third layer, everything that can be made in the cities requiring low or medium levels of investment, as changes in traffic lights or public lighting; and a fourth layer, encompassing substantive changes in structures or costly equipment.

Jorge Máximo

There are more areas within cities' administration that must be considered. Cities are a very complex ecosystem and there are several opportunities in areas such as sanitation, urbanism, city planning. It is important the connection of proposals with governance models; the framework may have good ideas, but they may not be deployable because governance does not allow it. Nowadays non-smart cities are not smart exactly because there are very divergent responsibilities, divided by too many entities. Lean Thinking itself must promote the integration between entities managing the public space in a combined way, creating Lean systems articulated with each other.

Luis Vidigal Rosado Pereira

I suggest the reference to initiatives stemming from the citizen, and not only the ones arising from public administration. I criticize the separation of "public administration" and "e-government", that makes no sense, they are the same dimension.

4.4. DISCUSSION OF RESULTS

All the specialists enquired consider that, in a theoretical plan, the framework presented may be useful for a Smart City manager. They believe, however, it is fundamental to consider other aspects such as, for example, the education of the citizen in order to take advantage of the solutions developed, the clear definition of the responsibilities of the actors involved in urban operations (management and utilization), a distribution of intervention competences making processes flow, a cost/benefit analysis to the proposals, and the development of recommendations for the citizens in the value co-production point of view.

It is unanimous for all the specialists that Lean Thinking is useful in managing a Smart City, being waste reduction the focus referred by them all. Among the recommendations, highlights for the structured way as Lean Thinking addresses waste, the transversal nature of the methodology to every kind of governance, the usefulness of the methodology in creating fluid processes and integration of systems, and the available technology allowing us to put Lean Thinking further into practice in a real-time logic of action supported by sensing and data analysis.

Specialists also suggested improvements and criticized the framework. One of the critics addresses the economic feasibility of the solutions: despite the decreasing cost of technology, for the present time it is necessary to assess the cost and impact of each one of the solutions and (i) prioritize the low cost and high impact solutions; (ii) plan the implementation of high cost and high impact solutions; (iii) equate the implementation of low cost and low impact solutions; and (iv) discard high cost and low impact solutions. Another criticism refers the fields of action, considering there are other fields where there are opportunities to work on. Finally, it is criticized the role of the citizen in the framework, it should be a central role with an active participation, but was seen as a passive agent that only uses the proposed solutions.

5. CONCLUSIONS

This research sought to find value in the utilization of Lean Thinking for managers of Smart Cities. Considering the opinions of relevant specialists, it was possible to meet the objectives of the research and assess this value.

It is essential to create an articulated Lean governance model, so the decision-making process is also free from waste, meaning, devoid from unnecessary steps. The adequate autonomy must also be attributed to the correct entity to avoid simple decisions to go through too many entities.

Not being possible to apply all the proposed measures to improve urban operations, the creation of a prioritization matrix will help to unveil the ones with a better cost/impact relation. Thus, the decision making regarding which proposals to implement is facilitated.

Citizens must have a fundamental role in urban operations, not being limited to a passive role of just using the services the city provides. A city must grant them the tools and skills necessary for them to use the technological solutions provided, but also to educate them in a way to use services and resources in a responsible and sustainable way.

5.1. SYNTHESIS OF WORK CONDUCTED

The present research investigation started with the background of the work to conduct, and what motivated it. Objectives to reach were defined.

Afterwards, resorting to an adequate literature review, Lean Thinking was studied, namely its origins and main features; the Smart Cities paradigm was also analyzed, in particular its roots and its evolution until today.

Subsequently, the investigation methodology was defined (opting for the Design Science Research methodology) and it was explained how it would be applied to this research investigation.

Based on the revised literature regarding the two fields of study, the Lean Thinking for Smart Cities framework was developed. The framework was then presented individually to three relevant specialists, for a subsequent discussion of the results.

5.2. INVESTIGATION LIMITATIONS

Notwithstanding the fact that the intention was to present a Lean Thinking for Smart Cities framework, and not final solutions for immediate application, some limitations to the work conducted were found.

The main limitation to this research work has to do with the quickness of the development of solutions for Smart Cities, forcing the extension of literature review to non-academic platforms and the risk of lack of accuracy it entails.

Another limitation of this research is the fact that citizens were not consulted regarding the acceptance or interest for the presented solutions.

A third limitation is the failure to check the feasibility of the framework proposals. It is to be confirmed, for example, if technologies on which proposals lay down were already developed or are expected to be developed in the future.

5.3. FUTURE WORK

Smart Cities solutions implementation itself must be smart. It is suggested therefore an analysis to the governance models in place, to assess and eliminate waste in the decision-making processes that may delay or negatively impact the realization of the solutions.

It is also proposed an analysis to the role of the citizen in a Smart City. This analysis should include not only measures to educate the citizen to live in the city of the future, but also recommendations on attitudes to have in the context of a sustainable and shared urban living.

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ANNEXES

Annex I: interviews script

The table of contents slide has a light grey header bar with the NOVA IMS logo on the left and the title 'Table of contents' in a large, bold, black font. Below the header, a vertical decorative element on the left consists of alternating yellow and dark grey rectangular blocks. To the right of this element, the table of contents is listed with bullet points:

- Research objective
- Framework presentation
- Questions

Research objective

- Lean Thinking
- Smart Cities

Lean Thinking

Lean - the set of activities that minimize organizational waste, improving value added activities. - Karim & Arif-Uz-Zaman (2013)

Desperdício - all activities embedded in the processes of an organization absorbing resources without adding value. - Stone (2012)

Defects
rework done due to errors

Overproduction
production in quantities
above the necessary

Waiting
time on hold
of a resource

Transportation
carrying objects
unnecessarily

Inventory
unfinished products or
products in need of storage

Movement
unnecessary movement
of people

Overprocessing
work not requested or
above demanded quality

Smart Cities

A city where investments in human and social capital, legacy infrastructures and disruptive technologies support its sustainable economic growth and high living standards, with a wise management of natural resources and a participatory governance - Deloitte (2015)

Cidade Inteligente

Domain	Main objectives
Tangible domains	
Energy grid	Effective energy provision, exchange of information regarding electricity consumption
Street lighting	Street lighting network effective management
Water management	Measurement of water consumption and leakage
Solid waste management	Definition of solid waste collection flow, destruction and recycling of solid waste
Natural environment	Usage of technology for environmental resources protection, pollution control
Transportation and mobility	Optimization of transportation networks considering traffic and energy consumption, real-time provision of traffic information
Buildings	Adoption of technology to create "living" buildings
Healthcare	Technology usage in remote assisted healthcare, diseases prevention and diagnose
Security	Real-time data transmission to security forces
Intangible domains	
Education and culture	Utilization of ICT tools in educational institutions, promotion of cultural events in online platforms
Social inclusion	Development of tools to decrease social barriers
Public administration and e-government	Development of online public services, electronic voting, shared governance
Economy	Promotion of innovation, entrepreneurship, the integration of the city in global markets, of circular economy models

Framework Lean SC

- Proposals / recommendations organization
- Proposals / recommendations

Proposals / recommendations organization

	1. Overproduction	2. Waiting	3. Transportation	4. Overprocessing	5. Inventory	6. Motion	7. Defects
A. Energy grid	A-15		A-3		A-15		A-7
B. Street lighting	BI-1						
C. Water management			C-3				C-7
D. Solid waste management	DM-1			D-46		D-46	
E. Natural environment	E-1			E-4		EF-6 / EG-6	
F. Transportation and mobility		FI-2				EF-6 / F-6	
G. Buildings	G-1					EG-6	
H. Healthcare		H-26				H-26	
I. Security	BI-1	FI-2					
J. Education and culture		J-2 / J-246		J-246		J-246	
K. Social inclusion							K-7
L. Public administration and e-government		L-26	L-37			L-26	L-37
M. Economy	DM-1 / M-1						

Proposals / recommendations

A-15 – utilization of technology to adjust the production and storage of electric energy

To be efficient, an energy grid should seek to produce the optimal quantity of electric energy. Overproduction of energy means a waste of resources, since part of this energy is dissipated; furthermore, the non-distributed energy implies its storage, using infrastructures meaning costs.

A way to circumvent this problem is to develop a system encompassing data collection sensors throughout the network, and adequate data analysis software, to predict the urban needs of energy and adequate the production according to the forecast.

Field of action	A. Energy grid
Type of waste targeted	1. Overproduction 5. Inventory

Proposals / recommendations

A-3 – least-effort principle applied to energy grid

A Smart Cities manager should require the planning of the electrical grid so that, amongst other indicators, the energy loss rate is as low as possible. This loss may happen, for example, due to the transformation of electric energy into thermal energy throughout the network.

A contribution to a decrease of this loss rate may be the redefinition of the distribution network (or the initial definition, in case it is to be applied to a city constructed from scratch) so the energy is transported through the shortest possible path.

Field of action	A. Energy grid
Type of waste targeted	3. Transportation

Proposals / recommendations

A-7 – detection of failures in the energy grid

A simple failure in the energy network may jeopardize the operation of, for example, houses, public and economic infrastructures, transportation means or street lighting.

To avoid the constraints caused by electric supply failures, it is suggested the introduction of failure detection sensors throughout the network, sending data to a central system that triggers alerts for quick detection of failures, so the appointing authorities can intervene faster.

Field of action	A. Energy grid
Type of waste targeted	7. Defects

Proposals / recommendations

BI-1 – Motion sensor for people and vehicles

Motion sensors placement throughout the paths with lighting needs, adjusting the light intensity along the way, enables the optimization of lighting production. This proposal has an impact in the decrease of public lighting costs, avoiding the overproduction of light (and subsequent energy expense) to supply the service.

Sustainable public lighting also increases the level of security (I) perceived by the citizen, helping to avoid phenomena such as robbery, pickpocketing or carjacking.

Field of action	B. Street lighting I. Security
Type of waste targeted	1. Overproduction

Proposals / recommendations

C-3 – least-effort principle applied to water supply

Water leakage is one of the biggest concerns for water management entities; as seen previously, it is estimated that 30% of the water provided is not billed. A Smart City manager may want to redefine the distribution network (or plan it, in case it is to be applied to a city constructed from scratch) so the water flow path is the shortest possible, reducing the potential spots where water leakage may occur.

Field of action	C. Water management
Type of waste targeted	3. Transportation

Proposals / recommendations

C-7 – water leakage detection

Another measure to decrease the lost water volume is the real-time detection of leakage spots. The quicker the leakage is detected, the smaller is the impact.

It is proposed the introduction of sensors throughout the network, sending data to a central system that triggers alerts when leakages are detected. This measure intends to reduce the impacts of defects in the water supply network, complementing the previous one: if it is not possible to reduce the whole number of water leakages, it is at least possible to decrease their impacts.

Field of action	C. Water management
Type of waste targeted	7. Defects

Proposals / recommendations

DM-1 – limitation to non-recyclable waste deposit

Solid waste, when properly separated, is a factor with influence in the environment and economic fields, not ending in a landfill and being reused as primary material in production processes. A way to increase the waste separation rate is to limit the quantity of non-recyclable waste produced.

This proposal suggests the implementation of small annexes in residential zones, where dumpsters are placed, with access via electronic key to identify the depositor. Within the annex, the citizen may deposit an unlimited quantity of recyclable waste, but a limited quantity of non-recyclable waste. Dumpsters must be equipped with proper technology to assess the material of the waste deposited.

Field of action	D. Solid waste management M. Economy
Type of waste targeted	1. Overproduction

Proposals / recommendations

D-46 – dumpster filling level sensing

Field of action	D. Solid waste management
Type of waste targeted	4. Overprocessing 6. Movement

Proposals / recommendations

E-1 – pollution levels sensing

Population concentration within the urban areas naturally increases the levels of pollution; two examples are noise and air pollution.

This proposal suggests the implementation of atmospheric and noise pollution sensors to assess which zones of the city are more affected by these disturbances. After data analysis, it will be easier to the appointed authorities to define priorities regarding intervention areas.

Field of action	E. Natural environment
Type of waste targeted	1. Overproduction

Proposals / recommendations

E-4 – humidity sensors for green areas

Green areas are essential to the urban environment, not only as socializing and leisure areas, but also for oxygen production. However, these spaces have water needs that may be addressed via irrigation or rainfalls.

This proposal suggests the introduction of humidity sensors in green areas with water needs, to assess the humidity levels of the area. The irrigation system will work if the humidity levels are low, due to the lack of rain, and will not work if humidity levels are enough to satisfy the water needs.

Field of action	E. Natural environment
Type of waste targeted	4. Overprocessing

Proposals / recommendations

EF-6 – least-effort principle applied to urban roads

The urban roads network is essential for a fluid motion of people and goods within the city. Smart City's routes should privilege not only the shortest path between two important points of the city, but also the priority to public transportation, motorcycles, electric vehicles and other transportation means less harmful to the environment.

Field of action	E. Natural environment F. Transportation and mobility
Type of waste targeted	6. Movement

Proposals / recommendations

FI-2 – smart traffic lights

Field of action	F. Transportation and mobility I. Security
Type of waste targeted	2. Waiting

Proposals / recommendations

F-6 – smart public-parking system

The search for vacant parking slots represents time and resources spent by drivers. The driving speed decreases, not only for the driver looking for a slot, but also impacting the other drivers. This proposal suggests the placement of parking sensors in street parking slots, so the driver is able to assess the occupation rate and free slots in a certain area via, for example, a smartphone app.

Field of action	F. Transportation and mobility
Type of waste targeted	6. Movement

Proposals / recommendations

G-1 – room presence sensors

For a more efficient utilization of buildings it is necessary their real-time suitability to their users' needs. It is easy to understand that an empty room does not justify the need of, for example, lighting or acclimatization, and therefore lights or air conditioning turned on mean a waste of resources.

The placement of presence sensors within a building's room, connected with a data processing software, allows the system to automatically adapt the room to the presence of people (e.g. adjusting luminosity, turning on air conditioning or wi-fi); when the room is left behind, equipment is turned off.

Field of action	G. Buildings
Type of waste targeted	1. Overproduction

Proposals / recommendations

G-6 – smart indoor-parking system

In occasions when a building car park is nearly full, it is useful for drivers looking for a vacant slot to know exactly where to find one, to reduce the time spent in the search.

It is suggested the placement of parking sensors, connected with a central data processing system that collects data and assesses vacant and occupied parking slots.

This information is provided to the users via, for example, a smartphone app.

Field of action	G. Buildings
Type of waste targeted	6. Movement

Proposals / recommendations

H-26 – healthcare remote monitoring

Field of action	H. Healthcare
Type of waste targeted	2. Waiting 6. Movement

Proposals / recommendations

J-2 – cultural infrastructures online guide

Monuments, concert halls and other cultural infrastructures attract tourists to the city and are also visited by residents. Naturally, there are infrastructures more requested by visitors causing waiting queues, while others are with few or no affluence.

This proposal suggests the development of visitors' redirection mechanisms as, for example, the distribution of flyers about less known infrastructures, or online guides presenting these alternatives. Municipalities can also develop an online service indicating in real-time the affluence to a certain infrastructure, so the visitor can decide better the time for a visit.

Field of action	J. Education and culture
Type of waste targeted	2. Waiting

Proposals / recommendations

J-246 – online educational services

Accessing educational services is essential for the development of urban population and the city itself, being an attraction factor of new residents. With the evolution of technology these services can become more efficient and accessible to a larger number of people.

Dematerialization of education, making it digital, allows students to experience educational services without visiting educational establishments. It is also possible to handle online bureaucratic services accessory to education services, such as enrolment submission or changes.

Field of action	J. Education and culture
Type of waste targeted	2. Waiting 4. Overprocessing 6. Movement

Proposals / recommendations

K-7 – promotion of technological learning for those in greatest need

With technology present in mainly all aspects of day-to-day life, citizens in greater need face the risk of technological exclusion. This proposal suggests Smart Cities' managers to implement programs directed to these citizens granting them the access to technological equipment, as well as training sessions regarding its use, to raise as much as possible the citizens' level of familiarity with technology.

Field of action	K. Social inclusion
Type of waste targeted	7. Defects

Proposals / recommendations

L-26 – online public bureaucratic services

This proposal aims the digitalization of all public services not requesting the presence of the citizen such as, for example, all paper forms. The request is made online, with the form being available instantly.

For services still requesting the presence of the citizen, it is suggested the development of electronic service tickets. The citizen can request a service ticket, or consult current the ticket and expected waiting time, via an app for smartphone.

Field of action	L. Public administration and e-government
Type of waste targeted	2. Waiting 6. Movement

Proposals / recommendations

L-37 – interactive guide for public bureaucratic processes

This proposal suggests the development of an interactive guide, available in digital format, and containing information regarding all the documentation needed to handle public bureaucratic processes. This guide intends to centralize all the information in one single place, avoiding its replication or dispersion.

Field of action	L. Public administration and e-government
Type of waste targeted	3. Transportation 7. Defects

Proposals / recommendations

M-1 – Incentive to the acquisition of recyclable materials

Transition from linear economy to circular economy models must be a priority, not only for Smart Cities but also for national governments. This proposal suggests these entities to gather efforts in a way to create the conditions to facilitate this transition, with, for example, incentives to the utilization of recycled materials opposed to the extraction of more raw resources. These incentives may come, for example, in the form of tax benefits.

Field of action	M. Economy
Type of waste targeted	1. Overproduction

Interview

- Do you think the proposed framework can be useful in Smart Cities management? Why?
- Do you think it is useful to apply Lean Thinking in managing a Smart City? Why?
- Do you have suggestions / criticism to the framework?