UNIVERSITAT DE BARCELONA

Evolving to Digital and Programmable Value Based Economy: General Prospect and Specific Applications over Sustainability

Ferran Herraiz Faixó

PhD in Business

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Thesis title:

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Dedicated to my family and all the people who have always questioned attitudes and kept advancing knowledge.

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continuing learning from during this amazing journey, many of whom are included in the reference section and many others who are not there. Thank you all for your amazing wisdom and for always inspiring and questioning me.

As Sir Isaac Newton (1643-1727) said*, "If I have seen further, it is by standing on the shoulders of giants."* In my case, I hope that with my humble contribution, we can go just a little further.

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List of Abbreviations

The following table describes the significance of various abbreviations and acronyms used throughout the thesis.

Abbreviation	Meaning
API	Application Programming Interface
AV	Autonomous Vehicles
C	Conduct
CAGR	Compound Annual Growth Rate
CEI	Competitive, Engagement and Innovation
CHG	Climate Greenhouse Gases
CO	Congestion
COG	Centre of Gravity
CP	Congestion Pricing
CV	Commercial Vehicles
DAO	Decentralized Autonomous Organizations
DAS	Decentralized Autonomous Society
DD	Digital Disruption
DE	Digital Ecosystem
DEE	Digital Ecosystem Equation
DEM	Digital Ecosystem Model
DESI	Digital Economy and Society Index
DLT	Distributed Ledger Technology
DT	Digital Transformation
DIPVABEM	Digital and Programmable Value Based Economy and Management
DVS	Digital Value to Society
E	External
ECOCIPEM	Environment-Corporations-Citizens-Programmable Economy Model
EENG	Employees Engagement Index
ESE	Environment-Social-Economy
EU28	European Union 28
EV	Electric Vehicles
FDI	Foreign Direct Inflow
FIS	Fuzzy Inference System
FISMUR	Fuzzy Inference System Municipal Recycling
FOM	First of Maximum
FISUC	Fuzzy Inference System Urban Congestion
GCI	Global Competitive Index
GDP	Gross Domestic Product
GII	Global Innovation Index
GPT	General Purpose Technology
GVA	Gross Value Added
H	High
HMN	Human-Machine-Network
ICT	Information and Communication Technologies
IoT	Internet of Things

L	Low
M	Medium
MOM	Mean of Maximum
MR	Municipal Recycling
MRa	Municipal Recycling actual
M2M	Machine-to-Machine
OECD	Organization for Economic Co-operation and Development
PE	Programmable Economy
PoW	Proof of Work
P2P	Peer to Peer
RO	Recycling Oriented
RPF	Recycling Policy Focus
S	Structure
SC	Smart City or Smart Cities
SCMM	Smart Congestion Management Model
SCP	Structure Conduct Performance
SCPUCOM	Structure Conduct Performance Urban Congestion Model
SDGs	Sustainable Developments Goals
SMS	Scaled Momentum Score
SSE	Steady State Economy
UP	Uncongestion Pricing
WEF	World Economic Forum
3Rs	Reduce, Reuse, Recycle

Chapter 1

Introduction

1.1. Presentation

Since the Internet arrived more than 20 years ago, and Information and Communication Technologies (ICT) and Digital Transformation (DT) have been embraced by people, the world has witnessed a great revolution. In particular, this metamorphosis is having an acute impact on the economy, business and management sphere, among others, with its enormous scope and effects. This change has motivated the acceleration of all variables included in these sciences. In business and management, it implies greater speed in decision-making processes and making changes in value propositions offered by organizations, forcing managers to continuously review and reflect. In the economy and organizational environments, new types of relationships appear every day between agents, such as machines to machines, humans to machines, and so on, compelling managers to rethink countries, cities or business models. Unstoppable different technologies emerge every day, and their velocity and connections are pushing people into a permanently vigilant state; citizens' and employees' role are transforming due to effects of substitution in the labour force, and a number of things, data or values are in permanent exchange mode. At the same time, wellbeing in states and cities is questioned, and great global challenges, such as sustainability or wealth distribution, and many more distrusted human principles occur in all directions, forcing people to rethink their models. Unquestionably, the current state of the world is being affected by the so-called fourth industrial revolution where available technologies and their interaction merge impacting along physical, digital and biological domains (Schwab, 2016).

The incursion of the DT phenomenon into daily life is completely modifying the set of options that people have, creating a multitude of answers and questions never before possible (Bauman, 2017). There is no doubt that the Internet, ICT and DT have entered people's lives and daily organizations in a global manner, which does not exclude that the transition to the digital society is still in a very early stage. In this sense, digital proliferation is at a time of full effervescence, and developing and developed countries are promoting new initiatives to avoid being left behind, with knowing the future consequences.

Equally, the permanent dilemma surrounding humanity's future advances has persisted over time, and many opinions appear related to how tech and progress can resolve present and future challenges. As Marcel Proust said (1871-1922), people sometimes believe that the present is the only possible state of things (Proust, 2000); however, the World Economic Forum says that technology can help to save the planet (Lambertini, 2018), whereas others claim that technology is never the main driver of social progress (Toyama, 2015). This debate continues, but the academic consensus increasingly considers that future progress and societal challenges in organizations, countries or cities should have considered the role of people much more (Winston, 2019).

Digital technology has exerted prominent effects on actual human wellbeing, but its propagation in organizations does not have a one-time effect; rather, it is an incessant advance following errors, learning and success stages. Nevertheless, these organizations are not prevented from experiencing imbalances caused by having a partial or too technical manner in their vision, resulting in losses that directly affect society in general. For this reason, the role played by digital technology should be reviewed regular by the agents, considering that digital or technical novelty diffusion is not always accompanied by a greater value proposition for consumers or citizens or more value added for countries' producers. Thus, business and organizational leaders should think what this large shift means by considering the human aspect more (Winston, 2019). In other words, it means that DT initiatives that focus exclusively on technological points of view while neglecting human factors or are approached from an autotelic perspective neglecting the advance of other significant variables should be reviewed (Kane *et al.*, 2019). Thus, a more integrated vision of digital phenomena could be explored to open the door to proposing whole new approaches that could help managers to propose new perspective analyses of the current and future digital impact.

In terms of economics and management, what digital technology can do to improve national progress is significant, but it is not an automatic and isolated task; rather, it requires multiple transdisciplinary approaches. The economic world in which humans live and the business reality itself are not easy to understand since they have several types of reality selections that humans can choose to analyse them. From a broad point of view, it could access to the reality through, one, two or three types of selections: by fundamental selection (things), natural selection (people, nature, organizations) or artificial selection (bits) (Wagensberg, 2002). Therefore, the picture of reality will depend on the number of selections that have been chosen. Thus, in regard to finding solutions to the challenges that organizations or humanity actually faces, the number of alternatives available will depend on whether the mapping mindset used is a partial or selective one or, on the contrary, whether the global selection of an integrated vision has been contemplated. The digital subject means that being more digital should require a more holistic approach, forcing digital economics and management researchers to reconsider single approaches in favour of more inclusive one. Hence, it is important for agents to consider what role digital technology will play in the future since it will be an option chosen by them as a goal by itself or as an integrated means.

In organizations, both at the microeconomic level (companies) and at the macroeconomic level (cities, countries), digital phenomena and information technology deployment are also intensive. Their expansion is offering advantages by enabling new approaches to management and multi-interaction between agents. From an economic point of view, one of the most important aspects of these technologies is that of facilitating the human propensity to exchange things and values. As Adam Smith (1723-1790) said, this propensity is one of the original principles of human being and a specific characteristic of people since the beginning (Smith, 1994). Actually, this propensity is accelerating because the Internet is evolving from the "Internet of information", which has made it easier for individuals to access products and launch businesses, to the "Internet of value", which is an online space in which individuals can instantly exchange value (Rossington, 2018). The latter allows businesses and organizations to explore new approaches to the treatment of who, what, when, where, and how exchanges can occur and, most importantly, to use this opportunity to integrate all agents and achieve one mission at the same time, permitting the redefining of complex problems and exploring new solutions for them.

What is discussed in this thesis revolves around exploring two large issues related to this. On the one hand, the thesis investigates how developed countries are carrying out their DT and whether it occurs in isolation or in an ecosystemic manner, as well as exploring what is going with their producers' value added performance at the same time. On the other hand, the thesis explores astonishing potential digital applications in cities related to “Internet of value” and how this opportunity could allow them and organizations to rethink their digital value strategies. In this case, this objective is related to solving one of the most important issues that humanity is actually facing, which is sustainability in cities.

Exploring both is one of the greatest challenges in the economic and management fields for nations, cities and organizations. Thus, how digital transformation could help them to advance value added and how digital applications could support them in overcoming challenges such as sustainability, including all agents and capturing values in the solution, are both challenges addressed in this thesis.

From the beginning, this work has focused on exploring the imbalances occurring between the levels of digitalization achieved by the countries that make up the European Union (EU28) with regard to other variables of great importance, such as value added, competitiveness, innovation and employee engagement, because all of them are components of a country’s progress. In this sense, the opportunity was detected to develop research in which the quantitative information that international organizations and institutions offer in this regard could be used, implementing models and methodologies related to decision making.

Moreover, in the course of this thesis, the opportunity to work on a research project arose, entitled "Study and analysis of opportunities for improvement of services to citizens and businesses and Smart Cities (SC) and/or other public organizations achieved with the use of Big Data", funded by an agreement between the Department of Business of the University of Barcelona and Telefónica Móviles España, SA. In this project, research initiatives were carried out within the field of digitalization in SC. It was here, placing the focus on these spaces, that I had the opportunity to explore the advantages that digitalization offers and particularly those related to the digital and programmable economy (PE), with the purpose of developing applications and concrete models that could highlight the importance of these ecosystems while helping to render these areas more sustainable in the future.

As will be seen later, these applications are focused on contributing to the treatment and better decision making about highly complex sustainability urban problems, such as urban congestion or recycling when these are managed by the agents as a sustainability value. Exploratory studies were used, including the knowledge of experts, some contrasted models as well as methodologies related to the Bayes´ Theorem, Theory of Forgotten Effects and the Fuzzy Sets Theory, to suggest later some models and frames that contribute to better decision making by agents.

All of this work was based on the idea that digital transformation has the potential to generate value for the agents, improving progress in countries, cities, organizations and society in general if it is analysed with a digital ecosystem mindset and its deployed with a programmable economy perspective. So, potential applications in business and management fields will be discovered in general and, in particularly, new ways to deal with the big issues such as sustainability in cities will be presented.

1.2. Justification

According to Word Economic Forum, digitalization has the potential to generate immense value for economy and society (Martin *et al.*, 2018) but it is by no means that this total value will be captured, balanced and redistributed by itself between the agents. So, new paradigms to assess it are needed and specific applications are wanted in order to capture it. DT can, for example drive progress through advancing economic value in countries or encouraging sustainability social value in cities that protecting their environment. Really, the agents are only beginning to understand the full implications of the digital revolution and new visions and approaches are needed to maximize the value that digitalization could deliver.

Actually, nations are exerting great efforts to digitize their economies, using their resources to compete in this race. From the mayoral point of view, digital performance has been checked by some digital indices, compounded essentially with technological variables or aspects related to it, showing the evolution of DT as a measure of countries' progress. This partial reality approach could be miss what is occurring with other progress variables, such Gross Value Added (GVA) as, according to Organization for Economic Cooperation and Development (OECD) a measure of producers' and industries' productivity (OECD, 2001). It is noted that countries' digital indices could focus so much on technological aspects in isolation, underestimating other important drivers and denoting a partial or unidimensional vision underlying DT. At an aggregate level, countries could be as before a mirage, gaining positions exclusively in technological variables while losing momentum in value added or other important variables, such as competitive or innovation. This imbalance can spoil decision making in favour of pushing some measures, such as digital ones, to the detriment of others and falling into the obsessive trap of using all available technology at any price without seeing the complete picture of macro-variable performance. Digital ecosystem visions, including the entire economic reality rather than a unidimensional vision, could help how countries' digital strategies operate and how value can be added.

On the other hand, from an applied perspective a new era has recently begun in the field of digitalization regarding the "Internet of value". This phenomenon could definitively alter the framework in which organizations or institutions with their services/products, consumers/citizens or machines and things can interact with each other exchanging value, allowing them to be integrated into the same network without middleman supervision, thus avoiding management friction. It is a so-called programmable economy (PE). A PE enables new exchanges of value (monetary and non-monetary) between people, organizations or machines and creates new business models by combining the physical world with the digital one (Gartner, 2015). Along this line, new management models are beginning to appear in organizations and particularly in SC using PE in attempt to find new applications for current and future human challenges. PE could contribute to solving one of most important challenges linked to realizing sustainability when it is considered as a value and as a source of competitiveness for organizations (United Kingdom Green Building Council, 2018).

From this disposition, it is important to develop new research projects to provide new approaches, models, methodologies, frameworks and applications regarding aspects related to these subjects, which revolve around digitalization challenges as a value driver in a broad sense and locally.

This thesis investigates the diversity of countries' DT approaches from a multidimensional point of view and how it impacts in their value-added performance. Until now, many studies have elaborated a unidimensional bias weightily focusing on technological variables, missing economic and management variables. Second, the thesis explores potential digital value applications, such as PE, in organization and cities and how the “Internet of value” opens up new ways to imagine the value. Third, this thesis discovers latent digital and programmable value based economy and management frameworks developing, such as sustainability as a value that can be manage it, that its included in the negative externalities box that cities face. Regarding this aspects, there have actually been few studies and exploratory works related to this topic and even fewer discussing the application of PE to sustainability. New models and practical uses that could contribute to solving this problem would be appreciated.

The research question formulated for these purposes is as follows.

Research Question:

In the fields of economics, business and management, how could digital transformation advance (push) value creation and reliably encourage (pull) value capture, exchange and distribution?

The following section considers the objectives of this thesis in greater detail.

1.3. Objectives

This thesis aim to fill that gap with a novel framework to support policy-makers, countries, cities and businesses address the potential value that can be generated and captured by digitalization combining digital transformation theoretical perspectives and reliable applications of it. For this, it is proposed to make new contributions related to DT in two main aspects: to explore DT countries’ mindsets when it relates to their value progress and to advance with the potential digital value applications in trusted way when it focus on sustainability in cities, as an example. Both perspectives, although it will be applied on different dimensions and purposes, have in common that they are focus on digital value and they want to explore the best way to maximize and capture the DT value’s potential for organizations and society. Thus, first, it will be analysed the importance of knowing clearly the digital ecosystem in which the agents are operating in order to reinforce the value creation by promoting the inclusivity of the endpoints involved in it through exploring value progress in countries, as an example. Secondly, it will be analysed how the digital value can be captured, exchanged and redistributed in trusted way over complex issues such as sustainability in cities by deploying concrete digital applications that include human reinforcement to, finally, closing the circle combining both perspectives in a single digital value framework.

To achieve these objectives in this thesis, own models are proposed, inspired by other theoretical models already contrasted, and some proven methodologies are used related to conditional probability, forgotten effects and fuzzy sets.

In a more concrete way, this thesis contains the following objectives explained in Table 1.1.

Table 1.1 Objectives of the Thesis

Objective	**Chapters**
Primary O_1: Present the state of the art of Digital Transformation Secondary $O_{1.1}$: Bibliometric analysis $O_{1.2}$: Conceptual framework related to Digital Transformation, Digital Economy, Digital Assets, Blockchain and DLT, Smart Cities, Reinforcement and Sustainability	2
Primary O_2: Discuss and develop a novel framework to support policy-makers, countries, cities and businesses address the potential value that can be generated and captured by digitalization through new perspectives about Digital and Programmable Economy in countries and Smart Cities by new models and frameworks using some methodological approaches. Secondary: $O_{2.1}$: Discuss the implications of actual Digital Transformation factors in countries from a multidimensional point of view. $O_{2.2}$: Argue the advantages of deploying end to end digital solutions and digital assets as a multidimensional approach. $O_{2.3}$: Explore some Programmable Economy applications in Smart Cities managing sustainability value exchange between participants.	3, 4, 5, 6
O_3: Primary Publish some articles to develop Digital and PE practical cases and useful applications. Secondary:	3, 4, 5, 6
$O_{3.1}$: Diffusion: Participate in some congresses and conferences.	Appendices
Source: The author	

In a broader way, the following objectives are pursued.

O_1: To carry out a quantitative analysis on the state of the art regarding the number of publications, major journals and authors, most cited articles, most prolific institutions in the field and areas of research showing the greater interest in it, identifying trends and main sources of information, as well as a review of the literature on the basic concepts included in the areas of DT, SC, human reinforcement and sustainability.

With this objective, it pursues showing the relevant quantitative information related to the evolution and trends of these subjects included in the thesis from publications indexed in the Web of Science database.

O_2: To contribute to the current literature with new perspectives about DT using recognized methodologies, such as conditional probability and Bayes Theorem, the Theory of Forgotten Effects, the Theory of Fuzzy Sets, and accepted theoretical models as a base of inspiration for the development of new ones. All of these perspectives should allow social agents to make better decisions when they want to deploy digital technology in nations, cities or organizations to understand better the connections between digital technology and value added or advance in its creation and expand the digital deployment stage in SC through the presentation of the advantages that the PE offers, contributing to resolve challenges related to sustainability in these spaces through the sustainability as a value that it can be captured it, exchanged it and distributed it between agents, all of this developing a novel framework address the potential value that can be generated and captured by digitalization through new perspectives about Digital and Programmable Economy.

O_3: To publish some articles in indexed journals with recognized quality and to present papers at some congresses in related areas of knowledge to disseminate the contributions of this thesis.

As a result of the applied methodologies and the models developed in the previous section, an article has been published in *Digital Transformation and Artificial Intelligence, Towards an Efficient and Equitable Model* (ISBN); another article has been published in *Advances in Intelligent Systems and*

Computing (Scopus Cite Score 2017 = 0.40), and the title of the special issue is: “Modelling and Simulation in Management Sciences"; another article is currently under evaluation by the *Journal of Intelligent & Fuzzy Systems* (Impact Factor JCR 2017: 1.426), and the title of the special issue is "Information and Fuzzy Systems in Management Science" and finally, an article is submitted in the *Journal Computer Science and Information Systems* (Impact Factor JCR 2017: 0.613), and the title of the special issue is "Information Systems and Business Intelligence in Management Science".

1.4. Methodology

In the present doctoral thesis, different techniques are used. First, conditional probability is used when it is known that a particular event has occurred, and it is desired to know the probability of success of another event. Second, forgotten effect techniques are used in order to obtain all the direct and indirect relationships that associate different sets of causes and effects. Third, fuzzy set techniques are used allowing the development of models to manage information problems when it is vague, imprecise or incomplete. The reason why these methodologies have been used was that they contribute to solve decision making process and they allow to manage information database when it is scarcity or imprecise. In particular, the most relevant techniques used are as follows.

1.4.1. Conditional Probability and Bayes Theorem

Conditioned probability refers to the probability of occurrence of a hypothesis, depending on the presence of new evidence and is it used to represent the relationship between what is known and what can be revealed in order to improve decision making (Berenson, 1992). Related to the last, the Bayes theorem (Thomas Bayes, 1702-1761) is a mathematical rule that allows researchers to combine new data with their existing knowledge where an event B occurred can be deducted from the probabilities of an event A. The Bayes theorem has had great applications throughout history and is currently used in the fields of physics, engineering, management and in the fields of information technology and decision-making. According to the Basel Committee on Banking Supervision, Bayes' theorem is very useful because it uses decision modes and utility modes which allow solving decision-making problems (Basel, 2003).

1.4.2. Forgotten Effects Theory

This model (Kaufmann *et al*., 1988) establishes a system to obtain all the direct and indirect relationships that associate different sets of causes and effects. The relevance of this model focuses on the treatment of incidence relationships at different levels, rescuing those relationships that at first were not identified by presenting a weak or zero relational level. These connections between causes and effects can be established by discovering those incidents between elements that initially might not have been considered "forgotten effects". This model has been widely applied in different fields of research and entrepreneurship (Gil-Lafuente *et al*., 2015).

1.4.3. Fuzzy Logic Theory

The Theory of Fuzzy Sets was introduced in 1965 by Lofti A. Zadeh. The idea resides the elements that make up human thought not being numbers but linguistic labels. According to the principle of incompatibility, as the complexity of a system increases, the ability to be precise decreases to the point that precision and meaning are exclusive characteristics (Zadeh, 1975). Based on this idea, fuzzy logic allows to represent common thought in a mathematical language based on the Theory of Fuzzy Sets and their characteristic functions. Fuzzy logic's applications have increased to the point of being considered a real revolution, developing a large number of extensions, such as soft computing, which covers fuzzy sets and fuzzy logic for approximate reasoning and the theory of possibility (Merigó-Lindahl, 2009).

Table 1.2 shows the different methodologies and tools used in each of the contributions of this research.

Table 1.2 Methodology and Application by Contribution

Contribution	Methodology	Application
Beyond the Digital Transformation Race	Conditional Probability/Bayes' Theorem Compound Annual Growth Rate (CAGR)	Digital Ecosystem
Digital Assets Horizon in Smart Cities: Urban Congestion Management by IoT, Blockchain/DLT and Human Reinforcement	Forgotten Effects (Kaufmann *et al.*, 1988)	Congestion Management by Digital Assets and Human Reinforcement
Digital and Programmable Economy Applications: A Smart Cities Congestion Case by Fuzzy Sets	Fuzzy Sets Theory (Zadeh, 1975) Mandami Fuzzy Method (Mandami, 1977) Toolbox Fuzzy Logic (Matlab, 2018)	Congestion Management by Programmable Economy and Human Reinforcement
Sustainable City by Connecting Critical Value Endpoints	Fuzzy Sets Theory (Zadeh, 1975) Mandami Fuzzy Method (Mandami, 1977) Toolbox Fuzzy Logic (Matlab, 2018)	Recycling Management by Programmable Economy and Human Reinforcement.

Source: The author

1.5. Structure

This thesis is structured in 7 Chapters grouped into two parts. First, the preliminary part comprises the first two chapters with the introduction and the state of the question. In the second part, contributions are presented in the form of articles published or in the process of being published, to subsequently presenting conclusions, implications, limitations and future lines of research. The content of each chapter is summarized below.

In Chapter 1, the introduction is presented as a preliminary part of the research, including the presentation, justification, methodology and structure of the thesis.

In Chapter 2, a state of the question is presented from a bibliometric analysis of Web of Science database publications, searching concepts related to DT (digital economy, digital assets, blockchain and DLT-Distributed Ledger Technology-), smart cities, reinforcement theory and sustainability as part of this investigation. The purpose of this analysis is to present relevant information about the evolution, trends and productivity of these issues. The second part of this chapter shows important theoretical concepts about DT in a broad sense and other concepts of vital importance used in this thesis (smart cities, human reinforcement, sustainability and brand activism).

In Chapter 3, the Digital Ecosystem Model (DEM) is presented. It combines the digitalization index of a set of European Union (EU28) countries with other variables, such as competitiveness, innovation, employee engagement and GVA, all of which are used by the countries as progress or productivity signs. In this qualitative study and through the application of one of the most important decision-making tools, the Bayesian theorem, and the calculation of conditioned probabilities, it is analysed the different digital ecosystem behaviours and also explore their DT imbalances compared to their value added evolution over a period of time. The dissemination strategy for Chapter 3 is presented in Table 1.3.

Table 1.3 Dissemination Strategy for Chapter 3

Title:	**Beyond Digital Transformation Race.**	
Objective:	To discover imbalances between EU28 countries' digital transformation and their value-added evolution over time.	
Methodology:	Qualitative research using contrasted models and Conditional Probability Bayes' Theorem.	
Publication Strategy:	1-Peer-Reviewed Publication	
	Journal Name	*Digital Transformation and Artificial Intelligence, Towards an Efficient and Equitable Model* (ISBN)
	Area	Economy and Management
	Status	Published June, 2017
	2-Conference Presentation	
	2-1 Conference Name	Second On/Off International Conference in Marketing Decision Making
	Location	Barcelona (Spain)
	Date	October 2017
	Status	Presented
	2-2 Conference Name	Third Catalonian Economy and Business Congress,
	Location	Barcelona (Spain)
	Date	May 2018
	Status	Presented
Source: The author		

In Chapter 4, an exploratory study is presented that aims to visualize the strengths of digitalization when applied in a multidimensional way in cities, the results of which could allow institutions and corporations to make better decisions and to use more effective measures for the optimal management under one of the more pressing problems in modern societies, such as sustainability derived from urban congestion. Using the methodology offered by the Theory of Forgotten Effects, based on the opinion of multidisciplinary experts, a new Smart Congestion Management Model (SCMM) is proposed that includes the application of positive and negative incentives in the use of vehicles in SC, the deployment of technologies related to the IoT, blockchain/DLT, smart contracts or tokenization; all of these elements make up the backbone of the model along with aspects related to motivation and value exchange. The dissemination strategy for Chapter 4 is presented in Table 1.4.

Table 1.4 Dissemination Strategy for Chapter 4

Title:	**Digital Asset Horizons in Smart Cities: Urban Congestion Management by IoT, Blockchain/DLT, and Human Reinforcement.**	
Objective:	Rethink urban mobility and traffic congestion by considering citizen participation, sustainability digital value and end-to-end solutions.	
Methodology:	Exploratory research using contrasted models and the Forgotten Effect Theory.	
Publication Strategy:	1-Peer-Reviewed Publication	
	Journal Name	*Advances in Intelligent Systems and Computing*, vol. 894. Springer, Modelling and Simulation in Management Sciences. MS-18 2018. (Scopus Cite Score 2017 = 0.40)
	Area	Computing, Economy and Management
	Status	Published March 2019
	2-Conference Presentation	
	2.1 Conference Name	International Conference on Modelling and Simulation
	Location	Girona (Spain)
	Date	June 2018
	Status	Presented
	2.2. Conference Name	Third On/Off International Conference in Marketing Decision Making
	Location	Barcelona (Spain)
	Date	November 2018
	Status	Presented

Source: The author

In Chapter 5, a new approach to the previous chapter is presented using the benefits of the application of the PE as a basis. This approach allows to interweave the value endpoints towards a common and concordant mission, such as the management of negative externalities occurring in SC and specifically deployment in the treatment of urban congestion from another perspective thanks to PE, allowing it to pull sustainability value exchanges among participants and cities' agents. For this purpose, the Structure-Conduct-Performance Urban Congestion Model (SCPUCOM) is presented. Using the methodology provided by the Fuzzy Logic Theory, based on the opinion of multidisciplinary experts, an inference algorithm is proposed to estimate urban congestion benefits when the model is applied, allowing institutions and organizations to make better decisions related to urban mobility and offering the possibility of SC managers reducing the negative externalities that occur in them induced by urban congestion. The dissemination strategy for Chapter 5 is presented in Table 1.5.

Table 1.5 Dissemination Strategy Chapter 5

Title:	**Digital and Programmable Economy Applications: A Smart Cities Congestion Case by Fuzzy Sets.**	
Objective:	Develop a Programmable Economy application to inspire sustainability value exchange in cities, allowing them to manage negative externalities, such an urban congestion.	
Methodology:	Exploratory study using contrasted models and Fuzzy Set Theory.	
Publication Strategy:	1-Peer-Reviewed Publication	
	Journal Name	*Journal of Intelligent & Fuzzy Systems* The title of the special issue is: Information and Fuzzy Systems in Management Science (Impact Factor JCR 2017: 1.426)
	Area	Information and Management Science
	Status	In revision
	2-Conference Presentation	
	Conference Name	Fifteenth International Conference on Technology, Knowledge and Society
	Location	Barcelona (Spain)
	Date	March 2019
	Status	Presented
	Award	Winner Emerging Scholar

Source: The author

In Chapter 6, it is going deeper into the PE, and an exploratory study is presented using the Environment Corporations Citizens Programmable

Economy Model (ECOCIPEM) as an alternative means to addressing the problems arising from municipal recycling from a holistic point of view, integrating the concepts related to brand activism, environment policy factors, and citizens' behaviours, all managed by a digital and PE allowing for sustainability value exchange among participants and the city's agents.

In this case, the methodology offered by the Fuzzy Sets Theory is used to visualize, based on the opinion of multidisciplinary experts and an inference algorithm that estimates how the recycling rate fluctuates for a set of SC, a better combination of SC inputs considering sustainability as a digital value that can be captured for social agents in order to make better decisions in the cities contributing to achieve more sustainable spaces. The dissemination strategy for Chapter 6 is presented in Table 1.6.

Table 1.6 Dissemination Strategy Chapter 6

Title:	**Sustainable City by Connecting Critical Endpoints.**	
Objective:	Develop a Programmable Economy application to inspire sustainability value exchange in cities allowing for the management of negative externalities, such as waste recycling.	
Methodology:	Exploratory study using contrasted models and Fuzzy Sets Theory.	
Publication	1-Peer-Reviewed Publication	
Strategy:	Journal Name	*Journal Computer Science and* Information Systems- The title of the special issue is: Information Systems and Business Intelligence in Management Science (Impact Factor JCR 2017: 0.613)
	Area	Business Intelligence and Management Science
	Status	Submitted
Source: The author		

In Chapter 7, the conclusions of this research and the possible implications, limitations and future lines of research that derive from it are presented.

Finally, in the section of annexes, other information and relevant contributions that I carried out in the thesis are presented.

Chapter 2

State of the Art

2.1. Bibliometric Analysis

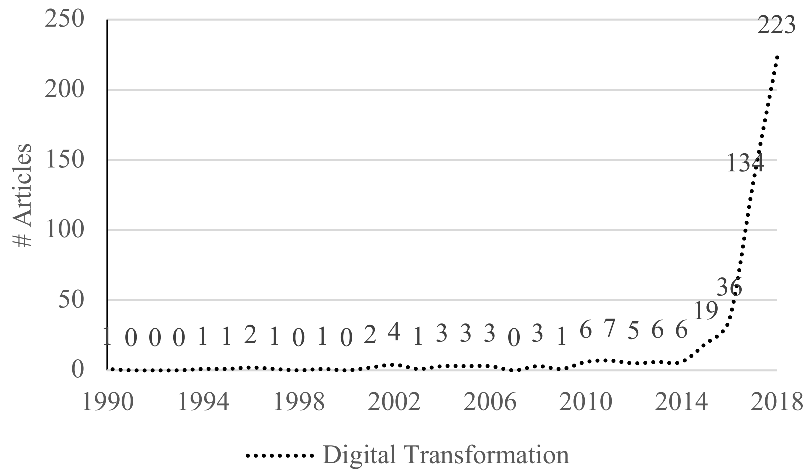
With the aim of determining in a generic way the evolution and impact of scientific publications, bibliometric analysis has become a fundamental tool. For this purpose, the analysis used the publications included in a search engine of recognized prestige for the quality and quantity of publications, such as Web of Science. The keywords search procedure has been through Web of Science Core collection visited on 02 and 03/ 2019, all topics, all authors, all publications name, all organizations, all funding agencies, all categories and all articles published from 1990 to 2018. It is important to note that there could be documents that contain the keywords used and that do not correspond to the subject of the study. Although this thesis addresses different issues related to digital technology in a broad sense and its applications, the analysis focuses on DT in its aspects of digital economy, digital assets, blockchain and DLT (Distributed Ledger Technology), together with SC, human reinforcement and sustainability.

2.1.1. Digital Transformation

The search process focused on the term "digital transformation" for the period of 1990-2018 and obtained 986 records. Subsequently, 469 published articles were selected, the data from which are presented in the following graphical analysis in Figure 2.1.

As can be seen, the interest in the subject is very positive with an increasing trend reaching a maximum of 223 publications in 2018 and a considerable boom starting in 2015.

Figure 2.1 Digital Transformation Publications Evolution



Source: The author through Web of Science

Table 2.1 presents the ten journals with the largest numbers of publications on digital transformation.

Table 2.1 Digital Transformation top ten Journals

Journal	# Articles	Share (%)
Digital Transformation in Journalism and News Media, Media Management, Media Convergence and Globalization	39	8.32
Media Journal and Innovation	39	8.32
Digital Transformation of the Consulting Industry Extending the Traditional Delivery Model	17	3,62
Progress in IS	17	3.62
Industry 4.0 Managing the Digital	16	3.41
Springer Series in Advanced Manufacturing	16	3.41
MIS Quarterly Executive	10	2.13
Bibliothek Forschung und Praxis	9	1.92
Cognitive Hyperconnected Digital Transformation Internet of Things Intelligence Evolution	9	1.92
Frontiers in Veterinary Science	9	1.92
Source: The author through Web of Science		

The number of publications per author, as Table 2.2 shows, reaches a maximum of 16 from Cevikcan, E. and Ustundag, A.

Table 2.2 Digital Transformation top ten Author

Author	# Articles	Share (%)
Cervikcan, E.	16	3.41
Ustundag, A.	16	3.41
Bacquet, T.	9	1.92
Nissen, V.	9	1.92
Vermesam, O.	9	1.49
Seifert, h.	7	1.49
Friedrichsen, M.	4	0.85
Anonymous	3	0.64
Benlian, A.	3	0.64
Hes, T.	3	0.64
Source: The author through Web of Science		

Table 2.3 shows the top ten countries by number of publications on digital transformation.

Table 2.3 Digital Transformation top ten Countries

Country	# Articles	Share (%)
Germany	105	22.39
USA	83	17.70
England	29	6.18
Spain	27	5.76
Russia	25	5.33
Switzerland	20	4.26
Turkey	18	3.84
Belgium	16	3.41
Sweden	16	3.41
Austria	5	1.07
Source: The author through Web of Science		

Table 2.4 shows the main institutions by number of publications on digital transformation.

Table 2.4 Digital Transformation top ten Institutions

Institutions	# Articles	Share (%)
Istanbul Tech Univ	17	3.62
EU	9	1.92
Sintef	9	1.92
Tech Univ Ilmenau	8	1.71
Daystar Univ	6	1.28
Univ Appl SCI Arts North-western Switzerland	6	1.28
Stanford Univ	5	1.07
Stuttgart Media Univ	5	1.07
Berlin Univ Digital SCI	4	0.85
MIT	4	0.85
Source: The author through Web of Science		

Table 2.5 shows the main field research areas in digital transformation.

Table 2.5 Digital Transformation top ten Fields Research Area

Field Research Area	# Articles	Share (%)
Business Economics	103	21.96
Computer Science	88	18.76
Communication	61	13.01
Engineering	61	13.01
Information Science Library Science	59	12.58
Science Technology Others Topics	18	3.84
Automation Control Systems	14	2.99
Education Educational research	14	2.99
Telecommunications	13	2.77
Public Administration	12	2.56

Source: The author through Web of Science

Table 2.6 shows the most cited articles on digital transformation.

Table 2.6 Digital Transformation most cited Articles

Article	Year	Author	Journal	Citations
Fast Discrete Curvelet Transforms	2006	Candes, Emmanuel; Demanet, Laurent; Donoho, David; Ying, Lexing	Multiscale Modelling & Simulation	1.011
The Digital Transformation of Healthcare: Current Status and the Road Ahead	2010	Agarwal, Ritu; Gao, Guodong (Gordon); DesRoches, Catherine; Jha, Ashish K	Information Systems Research	158
Innovation Diffusion in Global Contexts: Determinants of post-adoption Digital Transformation of European Companies	2006	Zhu, Kevin; Dong, Shutao; Xu, Sean Xin; Kraemer, Kenneth L.	European Journal of Information Systems	149
User Participation in Information Systems Security Risk Management	2010	Spears, Janine L.; Barki, Henri	Mis Quarterly	99
Quantifying your Body: A how-to Guide from a Systems Biology Perspective	2012	Smarr, Larry	Biotechnology Journal	41
Web-enabled Supply Chain Management: Key Antecedents and Performance Impacts	2011	Ranganathan, C.; Teo, Thompson S. H.; Dhaliwal, Jasbir	International Journal of Information Management	40
Digital Image-processing.1: Evaluation of gray-level Correction Methods in-vitro	1994	Fourmousis, I; Bragger, U; Burgin, W; Tonetti, M; Lang, NP	Clinical Oral Implants Research	39
Digital Transformation Strategies	2015	Matt, Christian; Hess, Thomas; Benlian, Alexander	Business & Information Systems Engineering	31
The Sharing Economy: Your Business Model's Friend or Foe?	2016	Kathan, Wolfgang; Matzler, Kurt; Veider, Viktoria	Business Horizons	26
The Digital Transformation of Traditional Businesses	2003	Andal-Ancion, A; Cartwright, PA; Yip, GS	Mit Sloan Management Review	25

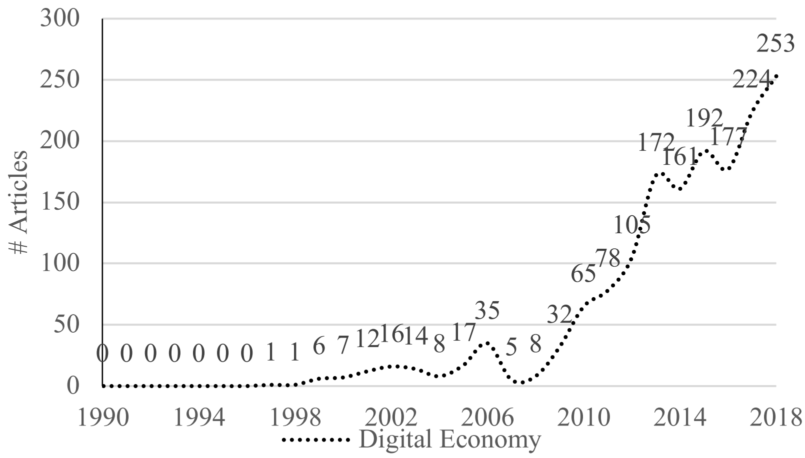
Source: The author through Web of Science

2.1.2. Digital Economy

The search process focused on the term "digital economy" for the period of 1990-2018 and obtained 3.098 records. Subsequently, 1.589 published articles were selected, the data from which are presented in the following graphical analysis in Figure 2.2.

As can be seen, the interest in the subject is very positive with an increasing trend reaching a maximum of 253 publications in 2018 and a considerable boom starting in 2011.

Figure 2.2 Digital Economy Publications Evolution



Source: The author through Web of Science

Table 2.7 presents the ten journals with the largest numbers of publications on digital economy.

Table 2.7 Digital Economy top ten Journals

Journal	# Articles	Share (%)
Plos One	20	1.26
Business Innovation Development and Advancement in the Digital Economy	17	1.07
Advances in e-Business Research AERB Book Series	15	0.94
Advances in Management Information Systems	15	0.94
Advances in Spatial Science	15	0.94
Driving Innovation and Business Success in the Digital Economy	15	0.94
E-Commerce and the Digital Economy	15	0.94
Emerging Digital Economy Entrepreneurship Clusters and Policy	15	0.82
BMC Bioinformatics	13	0.82
Constrains	13	0.82

Source: The author through Web of Science

The number of publications per author, as Table 2.8 shows, reaches a maximum of 32 for the authors Anderson, BDO. and Oncioiu, L.

Table 2.8 Digital Economy top ten Authors

Author	# Articles	Share (%)
Anderson, BDO.	32	2.01
Oncioiu, I.	32	2.01
Skafidas, E.	23	1.45
Nirmalathas, A.	18	1.13
Stuckey, P.J.	17	1.07
Brown, A.	14	0.88
Grindrod, P.	14	0.88
Smith, D.B.	14	0.88
Van de Val, R.	14	0.88
Clifford, G.D.	13	0.82
Source: The author through Web of Science		

Table 2.9 shows the top ten countries by number of publications on digital economy.

Table 2.9 Digital Economy top ten Countries

Country	# Articles	Share (%)
Australia	494	31.09
England	465	29.26
USA	258	16.24
Scotland	109	6.86
Russia	78	4.91
China	58	3.65
Canada	56	3.52
Germany	55	3.46
Spain	51	3.21
France	44	2.77
Source: The author through Web of Science		

Table 2.10 shows the main institutions by number of publications on digital economy.

Table 2.10 Digital Economy top ten Institutions

Institutions	# Articles	Share (%)
Univ Melbourne	150	9.44
Australian Natl Univ	133	8.37
Nicta	121	7.61
Univ Oxford	113	7.11
Univ Nottingham	90	5.66
Univ Aberdeen	55	3.46
Natl ICT Australia	53	3.34
Univ News Wales	53	3.34
Univ Cambridge	34	2.14
Manash Univ	31	1.95
Source: The author through Web of Science		

Table 2.11 shows the main field research areas in digital economy.

Table 2.11 Digital Economy top ten Field Research Area

Filed Research Area	# Articles	Share (%)
Computer Science	445	20.01
Business Economics	338	21.27
Engineering	310	19.51
Telecommunications	105	6.61
Government Law	82	5.16
Science Technology	77	4.85
Information Science	68	4.28
Communication	65	4.09
Mathematics	60	3.78
Geography	57	3.59
Source: The author through Web of Science		

Table 2.12 shows the ten most cited articles on digital economy.

Table 2.12 Digital Economy most cited Articles

Article	Year	Author	Journal	Citations
Wireless Body Area Networks: A Survey	2014	Movassaghi, Samaneh; Abolhasan, Mehran; Lipman, Justin; Smith, David; Jamalipour, Abbas	IEEE Communications Surveys and Tutorials	434
Consumer Surplus in the Digital Economy: Estimating the Value of Increased Product Variety at Online Booksellers	2003	Brynjolfsson, E; Hu, Y; Smith, MD	Management Science	335
Perceptions of Climate Change and Willingness to Save Energy Related to Flood Experience	2011	Spence, A.; Poortinga, W.; Butler, C.; Pidgeon, N. F.	Nature Climate Change	248
The Psychological Distance of Climate Change	2012	Spence, Alexa; Poortinga, Wouter; Pidgeon, Nick	Risk Analysis	226
Non-Intrusive Load Monitoring Approaches for Disaggregated Energy Sensing: A Survey	2012	Zoha, Ahmed; Gluhak, Alexander; Imran, Muhammad Ali; Rajasegarar, Sutharshan	Sensors	225
Uncertain Climate: An Investigation into Public Scepticism about Anthropogenic Climate Change	2011	Poortinga, Wouter; Spence, Alexa; Whitmarsh, Lorraine; Capstick, Stuart; Pidgeon, Nick F.	Global Environmental Change-Human and Policy Dimensions	221
Models for Supply Chains in e-Business	2003	Swaminathan, JM; Tayur, SR	Management Science	211
Institution-based Trust in Interorganizational Exchange Relationships: the Role of Online B2B Marketplaces on Trust Formation	2002	Pavlou, PA	Journal of Strategic Information Systems	184
Distributed Fault Detection for Interconnected Second-Order Systems	2011	Shames, Iman; Teixeira, Andre M. H.; Sandberg, Henrik; Johansson, Karl H	Automatica	159
Shadow Detection: A Survey and Comparative Evaluation of Recent Methods	2012	Sanin, Andres; Sanderson, Conrad; Lovell, Brian C.	Pattern Recognition	136

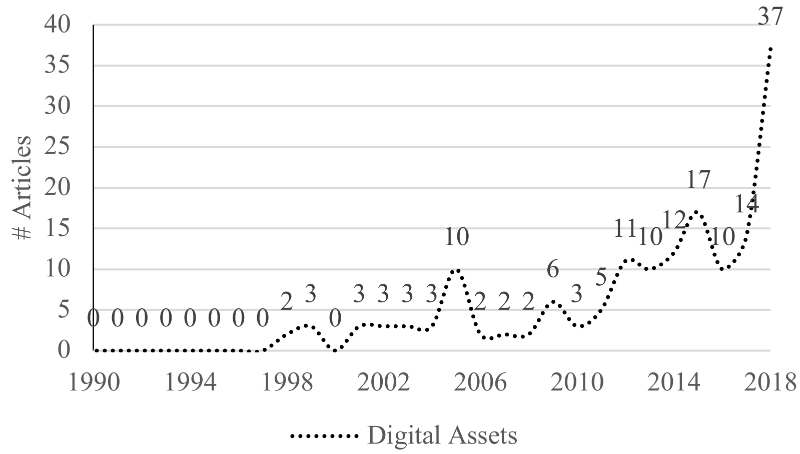
Source: The author through Web of Science

2.1.3. Digital Assets

The search process focused on the term "digital asset" for the period of 1990-2018 and obtained 453 records. Subsequently, 158 published articles were selected, the data from which are presented in the following graphical analysis in Figure 2.3.

As can be seen, the interest in the subject is very positive with an increasing trend reaching a maximum of 37 publications in 2018 and a considerable boom starting in 2016.

Figure 2.3 Digital Assets Publications Evolution



Source: The author through Web of Science

Table 2.13 presents the ten journals with the largest numbers of publications on digital assets.

Table 2.13 Digital Assets top ten Journals

Journal	# Articles	Share (%)
Content	6	3.80
Lecture Notes in Computer Science	5	3.16
Library Hi Tech	4	2.53
Computers Security	3	1.90
Library Research Technical Services	3	1.90
Library Trends	3	1.90
SMPTE Journal	3	1.90
Advances in Computers	2	1.27
Chandos Information Professional Series	2	1.27
Communications of the ACM	2	1.27

Source: The author through Web of Science

The number of publications per author, as shown in Table 2.14, presents an average of two articles for the first ten authors.

Table 2.14 Digital Assets top ten Author

Author	# Articles	Share (%)
Ke, T.	2	1.27
Cahn, N.	2	1.27
Chen, C.	2	1.27
Dougherty, W. C.	2	1.27
Dougherty, WC.	2	1.27
Gray, J.V.	2	1.27
Gray, JV.	2	1.27
Horton, D.	2	1.27
Horton, David	2	1.27
Kelly, EJ	2	1.27
Source: The author through Web of Science		

Table 2.15 shows the top ten countries by number of publications on digital assets.

Table 2.15 Digital Assets top ten Countries

Country	# Articles	Share (%)
USA	62	39.24
China	12	7.59
England	10	6.33
Germany	5	3.16
France	5	3.16
Netherlands	5	3.16
Spain	5	3.16
Australia	4	2.53
Canada	4	2.53
Ireland	4	2.53
Source: The author through Web of Science		

Table 2.16 shows the main institutions by number of publications on digital assets.

Table 2.16 Digital Assets top ten Institutions

Institutions	# Articles	Share (%)
Pennsylvania Commonwealth System of Higher Education	4	2.53
Ohio State Univ	3	1.90
Ohio State University	3	1.90
Penn State University	3	1.90
University of Amsterdam	3	1.90
University of London	3	1.90
Cornell Univ	2	1.27
Cornell University	2	1.27
George Washington University	2	1.27
Indiana University Northwest	2	1.27
Source: The author through Web of Science		

Table 2.17 shows the main field research areas in digital assets.

Table 2.17 Digital Assets top ten Field Research Area

Filed Research Area	# Articles	Share (%)
Computer Science	92	58.23
Information Science	36	22.78
Engineering	32	20.25
Business Economics	28	17.72
Government Law	26	16.46
Telecommunications	23	14.56
Educational Research	10	6.33
Communication	8	5.06
Imaging Science	7	4.43
Social Issues	7	4.43
Source: The author through Web of Science		

Table 2.18 shows the ten most cited articles on digital assets

Table 2.18 Digital Assets most cited Articles

Article	Year	Author	Journal	Citations
An Exploratory Study of Moral Intensity Regarding Software Piracy of Students in Thailand	2003	Kini, RB; Ramakrishna, HV; Vijayaraman, BS	Behaviour & Information Technology	33
A Blind Reversible Method for Watermarking Relational Databases Based on a Time-Stamping Protocol	2012	Farfoura, Mahmoud E.; Horng, Shi-Jinn; Lai, Jui-Lin; Run, Ray-Shine; Chen, Rong-Jian; Khan, Muhammad Khurram	Expert Systems with Applications	27
Understanding Modern Banking Ledgers Through Blockchain Technologies: Future of Transaction Processing and Smart Contracts on the Internet of Money	2016	Peters, Gareth W.; Panayi, Efstathios	Banking Beyond Banks and Money: a Guide to Banking Services in the Twenty-first Century	24
Man-At-The-End attacks: Analysis, Taxonomy, Human Aspects, Motivation and Future Directions	2015	Akhunzada, Adnan; Sookhak, Mehdi; Anuar, Nor Badrul; Gani, Abdullah; Ahmed, Ejaz; Shiraz, Muhammad; Furnell, Steven; Hayat, Amir; Khan, Muhammad Khurram	Journal of Network and Computer Applications	24
Shaping of Moral Intensity Regarding Software Piracy in University Students: Immediate Community Effects	2001	Ramakrishna, HV; Kini, RB; Vijayaraman, BS	Journal of Computer Information Systems	19
Boosting Servitization through Digitization: Pathways and Dynamic Resource Configurations for Manufacturers	2017	Coreynen, Wim; Matthyssens, Paul; Van Bockhaven, Woute	Ieee Transactions on Systems Man and Cybernetics part c-Applications and Reviews	16
Model Checking for e-Business Control and Assurance	2005	Anderson, BB; Hansen, JV; Lowry, PB; Summers, SL		14
Modelling the Digital Content Landscape in Universities	2008	Conway, Paul	Library hi Tech	13
How Watermarking Adds Value to Digital Content	1998	Acken, JM	Communications of the Acm	12
Managing the Investment in Information Security Technology by Use of a Quantitative Modelling	2012	Bojanc, Rok, Jerman-Blazic, Borka, Tekavcic, Metka	Information Processing & Management	11

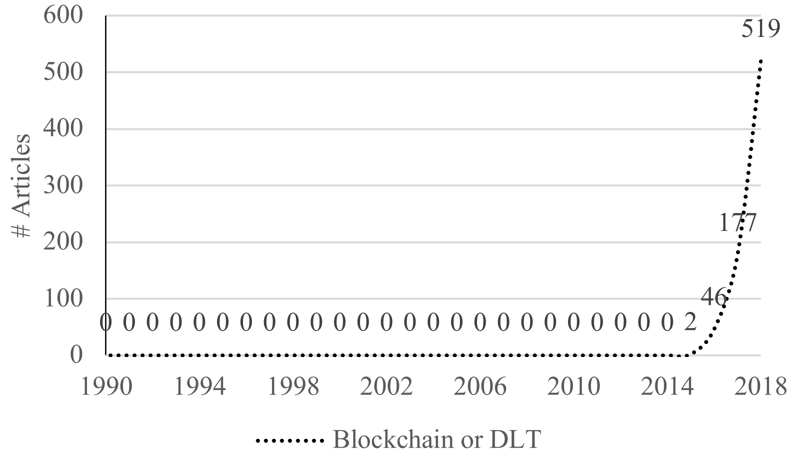
Source: The author through Web of Science

2.1.4. Blockchain and DLT

The search process focused on the term "blockchain" or “DLT” for the period of 1990-2018 and obtained 1.626 records. Subsequently, 744 published articles were selected, the data from which are presented in the following graphical analysis in Figure 2.4.

As can be seen, the interest in the subject is very positive with an increasing trend reaching a maximum of 519 publications in 2018 and a considerable boom starting in 2015.

Figure 2.4 Blockchain or DLT Publications Evolution



Source: The Author through Web of Science

Table 2.19 presents the ten journals with the largest numbers of publications on blockchain and DLT.

Table 2.19 Blockchain or DLT top ten Journals

Journal	# Articles	Share (%)
IEEE Access	55	7.39
Handbook of Blockchain Digital Finance and Inclusion Vol 2 Chinatech	22	2.96
Handbook of Blockchain Digital Finance and Inclusion Vol 1 Cryptocurr	20	2.69
Sensors	15	2.02
ERCIM News	12	1.61
Strategic Chance Briefings in Entrepreneurial Finance	12	1.61
Sustainability	11	1.48
European Review of Private Law	10	1.34
Journal of Medical System	10	1.34
Computer Law Security Review	9	1.21

Source: The author through Web of Science

The number of publications per author, as shown in Table 2.20, reaches a maximum of 9 publications led by Wang, J., and Zhang. Y.

Table 2.20 Blockchain or DLT top ten Authors

Author	# Articles	Share (%)
Wang, J.	9	1.21
Zhang, Y.	9	1.21
Androulaki, E.	8	1.08
Karame, G.	8	1.08
Choo, KKR.	7	0.94
Chuen, DLK.	7	0.94
Park, JH.	7	0.94
Adarsh, S.	6	0.81
Asharaf, S.	6	0.81
Hofmann, E.	6	0.81

Source: The author through Web of Science

Table 2.21 shows the top ten countries by number of publications on blockchain and DLT.

Table 2.21 Blockchain or DLT top ten Countries

Country	# Articles	Share (%)
USA	176	23.66
China	163	21.91
England	70	9.41
Germany	62	8.33
South Korea	46	6.18
Singapore	42	5.65
Australia	40	5.38
Italy	38	5.11
Switzerland	31	4.17
Russia	30	4.03

Source: The author through Web of Science

Table 2.22 shows the main institutions by number of publications on blockchain and DLT.

Table 2.22 Blockchain or DLT top ten Institutions

Institutions	# Articles	Share (%)
Beijing Univ. Post Telecommunications	16	2.15
UCL	16	2.15
Singapore Management Univ.	13	1.75
Swiss Fed. Inst. Technology	11	1.48
Chinese Acad SCI	9	1.21
Nec Labs Europe	9	1.21
Singapore Univ. Social SCI	9	1.21
Univ. Texas San Antonio	9	1.21
Xidian Univ.	9	1.21
IBM Res Zurich Lab.	8	1.08
Source: The author through Web of Science		

Table 2.23 shows the main field research areas in Blockchain and DLT.

Table 2.23 Blockchain or DLT top ten Field Research Area

Filed Research Area	# Articles	Share (%)
Computer Science	316	42.47
Business Economics	181	24.33
Engineering	134	18.01
Telecommunications	114	15.32
Government Law	70	9.41
Science Technology	34	4.57
Information Science	22	2.96
Chemistry	19	2.55
Energy Fuels	16	2.15
Instruments	16	2.15
Source: The author through Web of Science		

Table 2.24 shows the most cited articles on blockchain and DLT

Table 2.24 Blockchain or DLT most cited Articles

Article	Year	Author	Journal	Citations
Blockchains and Smart Contracts for the Internet of Things	2016	Christidis, Konstantinos; Devetsikiotis, Michael	IEEE Access	182
Bitcoin and Beyond: A Technical Survey on Decentralized Digital Currencies	2016	Tschorsch, Florian; Scheuermann, Bjoern	IEEE Communications Surveys and Tutorials	75
Industry 4.0 and the Current Status as Well as Future Prospects on Logistics	2017	Hofmann, Erik; Ruesch, Marco	Computers in Industry	52
An ID-Based Linearly Homomorphic Signature Scheme and Its Application in Blockchain	2018	Lin, Qun; Yan, Hongyang; Huang, Zhengan; Chen, Wenbin; Shen, Jian; Tang, Yi	IEEE Access	44
Healthcare Data Gateways: Found Healthcare Intelligence on Blockchain with Novel Privacy Risk Control	2016	Yue, Xiao; Wang, Huiju; Jin, Dawei; Li, Mingqiang; Jiang, Wei	Journal of Medical Systems	44
Designing Microgrid Energy Markets A Case Study: The Brooklyn Microgrid	2018	Mengelkamp, Esther; Gaerttner, Johannes; Rock, Kerstin; Kessler, Scott; Orsini, Lawrence; Weinhardt, Christof	Applied Energy	43
Blockchain Technology in the Chemical Industry: Machine-to-Machine Electricity Market	2017	Sikorski, Janusz J.; Haughton, Joy; Kraft, Markus	Applied Energy	40
The Truth about Blockchain	2017	Lansiti, Marco; Lakhani, Karin R.	Harvard Business Review	32
Enabling Localized Peer-to-Peer Electricity Trading Among Plug-in Hybrid Electric Vehicles Using Consortium Blockchains	2017	Kang, Jiawen; Yu, Rong; Huang, Xumin; Maharjan, Sabita; Zhang, Yan; Hossain, Ekram	IEEE Transactions on Industrial Informatics	25
MeDShare: Trust-Less Medical Data Sharing Among Cloud Service Providers via Blockchain	2017	Xia, Qi; Sifah, Emmanuel Boateng; Asamoah, Kwame Omono; Gao, Jianbin; Du, Xiaojiang; Guizani, Mohse	IEEE Access	24

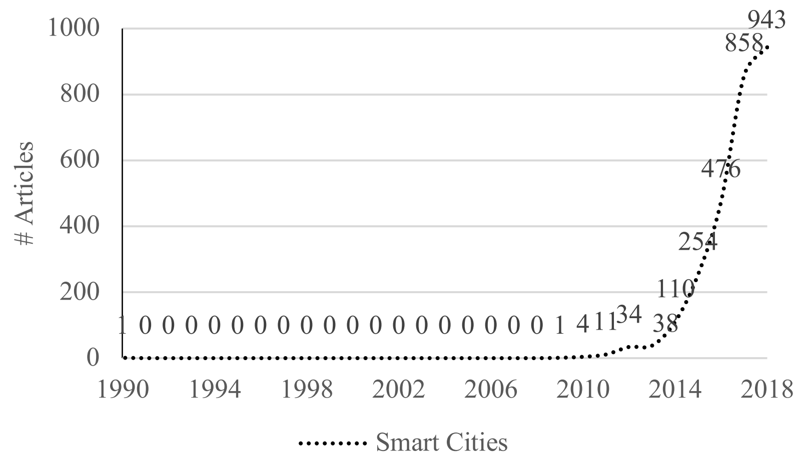
Source: The author through Web of Science

2.1.5. Smart Cities

The search process focused on the term "smart cities" for the period of 1990-2018 and obtained 6.983 records. Subsequently, 2.730 published articles were selected, the data from which are presented in the following graphical analysis in Figure 2.5.

As can be seen, the interest in the subject is very positive with an increasing trend reaching a maximum of 943 publications in 2018 and a considerable boom starting in 2015.

Figure 2.5 Smart Cities Publications Evolution



Source: The Author through Web of Science

Table 2.25 presents the ten journals with the largest numbers of smart cities publications.

Table 2.25 Smart Cities top ten Journals

Journal	# Articles	Share (%)
Sensors	150	5.49
IEEE Access	101	3.70
Urban Books Series	56	2.05
Future Generation Computer Systems. The International Journal of Science	50	1.83
IEEE Communications Magazine	48	1.76
Sustainability	48	1.76
Advances in 21st Century Human Settlements	47	1.72
Sustainable Smart Cities in India Challenges and Future Perspective	46	1.68
IEEE Internet of Things Journal	40	1.47
Smart Economy in Smart Cities	36	1.32
Source: The author through Web of Science		

The number of publications per author, as Table 2.26 shows, reaches a maximum of 45 from Bustince, H.

Table 2.26 Smart Cities top ten Authors

Author	# Articles	Share (%)
Bustince, H.	45	1.65
Li, J.	31	1.14
Beruete, M.	29	1.06
Wang, C.	27	0.99
Carvalho, LC.	24	0.88
Matias, IR.	22	0.81
Ercoskun, OY.	20	0.73
Arregui, FJ.	17	0.62
Falcone, F.	17	0.62
Pop, F.	17	0.62
Source: The author through Web of Science		

Table 2.27 shows the top ten countries by number of publications on smart cities.

Table 2.27 Smart Cities top ten Countries

Country	# Articles	Share (%)
Spain	516	18.90
Italy	415	15.20
USA	368	13.48
China	345	12.64
England	226	8.28
India	166	6.08
Canada	134	4.91
Australia	111	4.07
Germany	100	3.66
Brazil	87	3.19
Source: The author through Web of Science		

Table 2.28 shows the main institutions by number of publications on smart cities.

Table 2.28 Smart Cities top ten Institutions

Institutions	# Articles	Share (%)
Univ. Public. Navarra	185	6.78
CNR	38	1.39
Politecn Torino	35	1.28
Xiamen Univ.	34	1.25
Shenzhen Univ.	33	1.21
Univ Waterloo	33	1.21
Univ. Politehn Bucuresti	31	1.14
Chinese ACAD SCI	27	0.99
Politecn Milan	27	0.99
Univ. Bologna	26	0.95

Source: The author through Web of Science

Table 2.29 shows the main field research areas in smart cities.

Table 2.29 Smart Cities top ten Field Research Area

Filed Research Area	# Articles	Share (%)
Computer Science	903	33.08
Engineering	733	26.85
Telecommunications	487	17.84
Urban Studies	411	15.05
Science Technology	238	8.72
Public Administration	233	8.53
Business Economics	209	7.66
Instruments Instrumentations	199	7.29
Chemistry	197	7.22
Environmental Sciences Ecology	197	7.22

Source: The author through Web of Science

Table 2.30 shows the ten most cited articles on smart cities.

Table 2.30 Smart Cities most cited Articles

Article	Year	Author	Journal	Citations
Internet of Things for Smart Cities	2014	Zanella, Andrea; Bui, Nicola; Castellani, Angelo; Vangelista, Lorenzo; Zorzi, Michel	IEEE internet of Things Journal	965
Smart Cities in Europe	2011	Caragliu, Andrea; Del Bo, Chiara; Nijkamp, Peter	Journal of Urban Technology	545
Smart Cities of the Future	2012	Batty, M.; Axhausen, K. W.; Giannotti, F.; Pozdnoukhov, A.; Bazzani, A.; Wachowicz, M.; Ouzounis, G.; Portugali, Y.	European Physical Journal-Special Topics	352
Smart Cities: Quality of Life, Productivity, and the Growth Effects of Human Capital	2006	Shapiro, JM	Review of Economics and Statistics	329
An Information Framework for Creating a Smart City Through Internet of Things	2014	Jin, Jiong; Gubbi, Jayavardhana; Marusic, Slaven; Palaniswami, Marimuthu	IEEE Internet of Things Journal	303
Smart Cities and the Future Internet: Towards Cooperation Frameworks for Open Innovation	2011	Schaffers, Hans; Komninos, Nicos; Pallot, Marc; Trousse, Brigitte; Nilsson, Michael; Oliveira, Alvar	Future Internet: Future Internet Assembly 2011: Achievements and Technological Promises	272
Sensing as a Service Model for Smart Cities Supported by Internet of Things	2014	Perera, Charith; Zaslavsky, Arkady; Christen, Peter; Georgakopoulos, Dimitrios	Transactions on Emerging Telecommunications Technologies	262
Smart Cities: Definitions, Dimensions, Performance, and Initiatives	2015	Albino, Vito; Berardi, Umberto; Dangelico, Rosa Maria	Journal of Urban Technology	233
Modelling the Smart City performance	2012	Lombardi, Patrizia; Giordano, Silvia; Farouh, Hend; Yousef, Wael	Innovation-the European Journal of Social Science Research	148
Enabling Smart Cities through a Cognitive Management Framework for the Internet of Things	2013	Vlacheas, Panagiotis; Giaffreda, Raffaele; Stavroulaki, Vera; Kelaidonis, Dimitris; Foteinos, Vassilis; Poulios, George; Demestichas, Panagiotis; Somov, Andrey; Biswas, Abdur Rahim; Moessner, Klaus	IEEE Communications Magazine	139

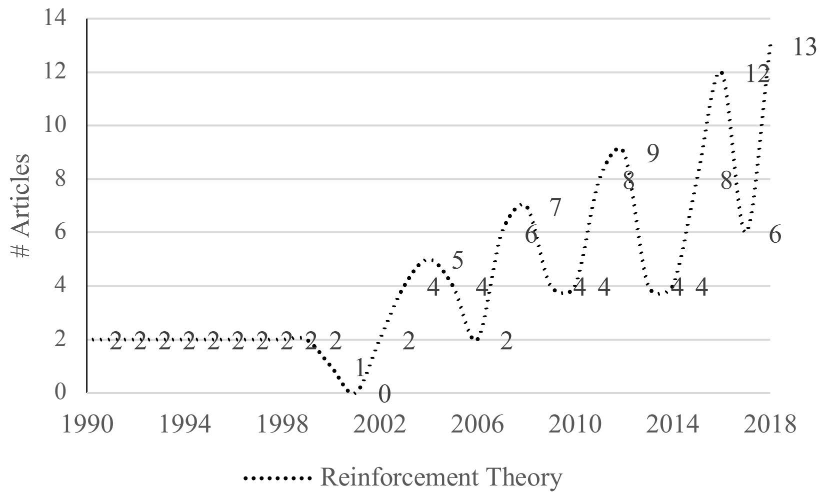
Source: The author through Web of Science

2.1.6. Reinforcement Theory

The search process focused on the term "reinforcement theory" for the period of 1990-2018 and obtained 181 records. Subsequently, 123 published articles were selected, the data from which are presented in the following graphical analysis in Figure 2.6.

As can be seen, the interest in the subject is very positive with an increasing trend reaching a maximum of 13 publications in 2018 with an intermittent increase from 2004.

Figure 2.6 Reinforcement Theory Publications Evolution



Source: The author through Web of Science

Table 2.31 presents the ten journals with the largest numbers of publications on Reinforcement Theory.

Table 2.31 Reinforcement Theory top ten Journals

Journal	# Articles	Share (%)
Journal of Experimental Analysis of Behavior	6	4.88
Behavioral Processes	5	4.07
Computers and Geotechnics	4	3.25
Composite Science and Technology	3	2.44
Rock and Soil Mechanics	3	2.44
Science in China Series Technological Science	3	2.44
Social Behavior and Personality	3	2.44
Applied Mechanics and Materials	2	1.63
Journal of Central South University	2	1.63
South University Science Technology	2	1.63

Source: The author through Web of Science

The number of publications per author, as shown in Table 2.32, reaches a maximum of 20 publications by Yang, Q.

Table 2.32 Reinforcement Theory top ten Authors

Author	# Articles	Share (%)
Yang, Q.	20	16.26
Liu, YR.	19	15.45
Liu, Y. R.	10	8.13
Qiang Yang	7	5.69
Yaoru, L.	6	4.88
Deng, J.Q.	5	4.07
Deng, JQ.	5	4.07
Pan, PW.	5	4.07
Yang, Quiang	5	4.07
Klasztorny, M.	4	3.25
Source: The author through Web of Science		

Table 2.33 shows the top ten countries by number of publications on Reinforcement Theory.

Table 2.33 Reinforcement Theory top ten Countries

Country	# Articles	Share (%)
USA	49	39.84
R.China	32	26.02
China	20	16.26
England	7	5.69
UK	7	5.69
New Zealand	6	4.88
Germany	5	4.07
Canada	4	3.25
Poland	4	3.25
Taiwan	3	2.44
Source: The author through Web of Science		

Table 2.34 shows the main institutions by number of publications on Reinforcement Theory.

Table 2.34 Reinforcement Theory top ten Institutions

Institutions	# Articles	Share (%)
Tsinghua University	20	16.26
Tsinghua Univ.	4	3.25
Univ. New Hampshire	4	3.25
University of New Hampshire	4	3.25
University System of New Hampshire	4	3.25
Warsaw Univ. Tech.	4	3.25
Warsaw University of Technology	4	3.25
Schlumberger	3	2.44
South China University of Technology	3	2.44
Univ. Auckland	3	2.44

Source: The author through Web of Science

Table 2.35 shows the main field research areas in Reinforcement Theory.

Table 2.35 Reinforcement Theory top ten Field Research Areas

Filed Research Area	# Articles	Share (%)
Behavioral Science	45	36.59
Psychology	44	35.77
Engineering	34	27.64
Business Economics	23	18.70
Materials Science	22	17.89
Mathematics	22	17.89
Neuroscience Neurology	20	16.26
Zoology	18	14.63
Mechanics	17	13.82
Physics	14	11.38

Source: The author through Web of Science

Table 2.36 shows the ten most cited articles on Reinforcement Theory

Table 2.36 Reinforcement Theory most cited Articles

Article	Year	Author	Journal	Citations
A Dual Process Model of Perfectionism Based on Reinforcement Theory.	1998	Slade, PD; Owens, RG	Behavior Modification	176
Place Conditioning Reveals the Rewarding Aspect of Social-Interaction in Juvenile Rats	1992	Calcagnetti, DJ; Schechter, MD	Physiology & Behavior	168
Free Food or Earned Food? A Review and Fuzzy Model of Contrafreeloading	1997	Inglis, IR; Forkman, B; Lazarus, J	Animal Behaviour	134
Distress Tolerance and Early Adolescent Externalizing and Internalizing Symptoms: The Moderating Role of Gender and Ethnicity	2009	Daughters, Stacey B.; Reynolds, Elizabeth K.; MacPherson, Laura; Kahler, Christopher W.; Danielson, Carla K.; Zvolensky, Michael; Lejuez, C. W.	Behaviour Research and Therapy	82
Effect of Firing Conditions, Filler Grain Size and Quartz Content on Bending Strength and Physical Properties of Sanitaryware Porcelain	2004	Stathis, G; Ekonomakou, A; Stournaras, CJ; Ftikos, C	Journal of the European Society	80
Faculty Rank System, Research Motivation, and Faculty Research Productivity - Measure Refinement and Theory Testing	1996	Tien, FF; Blackburn, RT	Journal of Higher Education	71
A Conventional Conditioning Analysis of Transitive Inference in Pigeons	1992	Couvillon, PA; Bitterman, ME	Journal of Experimental Psychology-Animal Behavior Processes	67
The Silver Lining of Materialism: The Impact of Luxury Consumption on Subjective Wellbeing	2012	Hudders, Liselot; Pandelaere, Mario	Journal of Happiness Studies	61
Sexual Isolation between Two Sibling Species with Overlapping Ranges: Drosophila Santomea and Drosophila Yakuba	2002	Coyne, JA; Kim, SY; Chang, AS; Lachaise, D; Elwyn, S	Evolution	59
Functional Thiol Ionic Liquids as Novel Interfacial Modifiers in SBR/HNTs Composites	2011	Lei, Yanda; Tang, Zhenghai; Zhu, Lixin; Guo, Baochun; Jia, Demin	Polymer	54

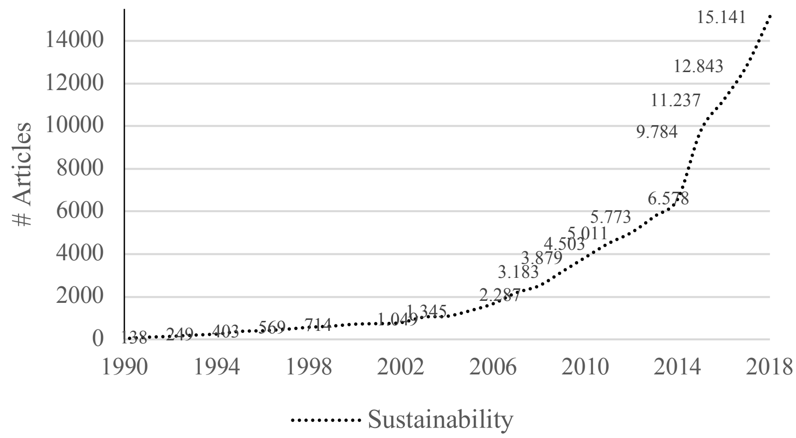
Source: The author through Web of Science

2.1.7. Sustainability

The search process focused on the term "sustainability" for the period of 1990-2018 and obtained 97.177 records. Subsequently, 93.149 published articles were selected, the data from which are presented in the following graphical analysis in Figure 2.7.

As can be seen, the interest in the subject is very positive with an increasing trend reaching a maximum of 15.141 publications in 2018 and a considerable boom starting in 2000.

Figure 2.7 Sustainability Publications Evolution



Source: The author through Web of Science

Table 2.37 presents the ten journals with the largest numbers of publications on sustainability.

Table 2.37 Sustainability top ten Journals

Journal	# Articles	Share (%)
Sustainability	3.213	3.45
Journal of Cleaner Production	3.094	3.32
Ecological Economics	898	0.96
Energy Policy	554	0.59
Ecological Indicators	524	0.56
Plos One	484	0.52
Journal of Environmental Management	479	0.51
Ecology and Society	439	0.47
Science of the Total Environment	436	0.47
Marine Police	432	0.46
Source: The author through Web of Science		

The number of publications per author, as shown in Table 2.38, reaches a maximum of 121 articles by Zhang, Y.

Table 2.38 Sustainability top ten Authors

Author	# Articles	Share (%)
Zhang, Y,	121	0.13
Liu, Y.	102	0.11
Wang, Y.	94	0.10
Li, I.	91	0.10
Zhang, J.	89	0.10
Dincer, I.	83	0.09
Wang, J.	83	0.09
Kim, J.	79	0.08
Singh, S.	76	0.08
Kim, S.	75	0.08
Source: The author through Web of Science		

Table 2.39 shows the top ten countries by number of publications on sustainability.

Table 2.39 Sustainability top ten Countries

Country	# Articles	Share (%)
USA	22.969	24.66
England	9.322	10.01
Australia	7.174	7.69
China	6.500	6.98
Canada	5.775	6.20
Germany	5.444	5.84
Italy	4.914	5.28
Spain	4.899	5.26
Netherlands	4.234	4.55
Brazil	3.915	4.20
Source: The author through Web of Science		

Table 2.40 shows the main institutions by number of publications on sustainability.

Table 2.40 Sustainability top ten Institutions

Institutions	# Articles	Share (%)
Chinese Acad SCI	1.158	1.24
Univ British Columbia	751	0.81
Wageningen Univ	691	0.74
Arizona State Univ	641	0.69
Uni Queensland	595	0.64
Univ Sao Paolo	517	0.56
INRA	510	0.55
Univ Toronto	485	0.52
Dellft Univ Technol	479	0.51
Univ Melbourne	475	0.51
Source: The author through Web of Science		

Table 2.41 shows the main field research areas in sustainability.

Table 2.41 Sustainability top ten Fields Research Area

Field Research Area	# Articles	Share (%)
Environmental Science Ecology	28.758	30.87
Engineering	14.310	15.36
Science Technology	13.707	14.72
Business Economics	13.689	14.70
Agriculture	8.459	9.08
Energy Fuels	4.433	4.76
Water Resouces	3.895	4.18
Social Science	3.767	4.04
Public Administration	3.616	3.89
Education	3216	3.45
Source: The author through Web of Science		

Table 2.42 shows the ten most cited articles on Sustainability.

Table 2.42 Sustainability most cited Articles

Article	Year	Author	Journal	Citations
Solutions for a Cultivated Plane	2011	Foley, Jonathan A.; Ramankutty, Navin; Brauman, Kate A.; et al.	Nature Vol: 478 N: 7369 P: 337-342	2.121
Fostering Implementation of Health Services Research Findings into Practice: a Consolidated Framework for Advancing Implementation Science	2009	Damschroder, Laura J.; Aron, David C.; Keith, Rosalind E.; et al.	Implementation Science Vol: 4	2.077
Sustainable Hydrogen Production	2004	Turner, JA	Science Vol: 305 N.5686 Pg: 972-974	2.033
Vulnerability	2005	Adger, W. Neil	Workshop on Vulnerability, Resilience AdaptationUbicación: Arizona State Univ, Tempe, AZ	1.852
Resilience, Adaptability and Transformability in Social-Ecological Systems	2004	Walker, B; Hollin, CS; Carpenter, SR; et al.	Ecology and Society Vol: 9 N: 2 NA: 5	1.389
Rebuilding Global Fisherie	2009	Worm, Boris; Hilborn, Ray; Baum, Julia K.; et al.	Science Vo: 325 N: 5940 P: 578-585	1.138
Successful Adaptation to Climate Change across Scales	2005	Adger, WN; Arnell, NW; Tompkins, EL	Dimensions Vol: 15 N: 2	1.025
A Framework of Sustainable Supply Chain Management: Moving toward New Theory	2008	Carter, Craig R.; Rogers, Dale S.	International Journal of Physical Distribution & Logistics Management	961
Planetary Boundaries: Exploring the Safe Operating Space for Humanity	2009	Rockstrom, Johan; Steffen, Will; Noone, Kevin; et al.	Ecology and Society Vol 14 N: 2	934
Science for Managing Ecosystem Services: Beyond the Millennium Ecosystem Assessment	2009	Carpenter, Stephen R.; Mooney, Harold A.; Agard, John; et	Proceedings of the National Academy of Sciences of the United States of America Vol: 106	926

Source: The author through Web of Science

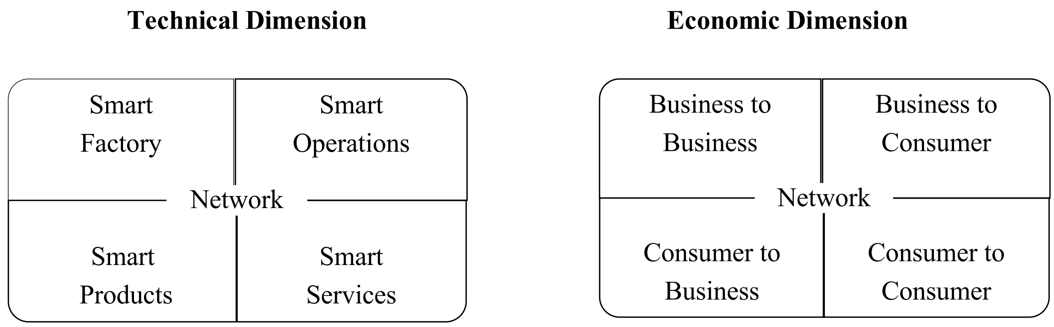
2.2. Digital Transformation

The literature review indicates that digital would be all forms and uses of information and technology electronically manageable through a series of coded impulses that represent 1s and 0s as a binary code (Gartner, 2017). For other authors, digital means allow for connecting people, devices and physical objects anywhere in an instant and at a low cost (Bughin *et al*., 2018) or could be considered to be the transformation of atoms into bits (Negroponte, 1995). This alteration from the tangible to the intangible, from atoms to bits, should not be understood as a replacement exclusively. Rather, it is that countries, companies, institutions and their citizens, in short all agents, should seek the best possible combination of physical and digital resources to be efficient. The idea that digital technology simply replaces the analogue world with a digital one remains far away. It is rather that, using both resources, countries and agents should understand their relationships and the flows between them that are derived to create innovative combinations (McDonald *et al*., 2012).

For other scholars, the concept of DT, also called digitalization (Henriette *et al*., 2015; Hüther, 2016), is defined as being a social phenomenon (Stolterman *et al*., 2004) or cultural evolution (Belk, 2016) for organizations and institutions or holistic transformation of organizations in the search for the creation of value-producing opportunities or new business models in the process of moving to a digital business transforming marketing functions (Zhu *et al*., 2006; Gartner, 2019; Henriette *et al*., 2016). On the contrary, the term digitization means converting from analogue to digital, in other words it takes an analogue process and changes it to a digital form without any changes to the process itself (Gartner, 2019).

Following the model of Hüther on the effects of digitalization by its context (Hüther, 2016), it is concluded that it is materialized through the implementation of two dimensions. On the one hand, the economic dimension would affect the new business models pursuing monetization, and on the other hand, there is one's own expansion of the technological dimension that makes the first possible, as seen in Figure 2.8.

Figure 2.8 Effects of Digitalization



Source: The author. Framework adapted from Hüther (Hüther, 2016)

From the technical point of view, digitalization affects production processes in the physical and virtual senses making it possible to standardize them. On the side related to networks, it is deployed through the development of market platforms (Shy, 2001). Similarly, it generates new relationships between producers and consumers and new interfaces between them while enabling peer-to-peer relationships by which consumers can temporarily transfer the exchange, the use of rights or the possibility of offering services by promoting the so-called collaborative economy, which has arisen as a phenomenon (Hüther, 2016).

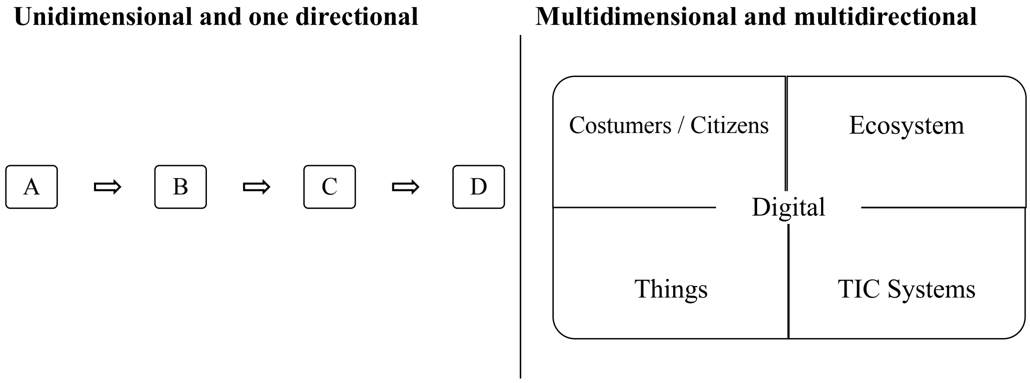
Focusing on the strategic perspective, digitalization should serve five domains; competence, data, innovation, clients/citizens and value (Rogers, 2016).

With all these definitions and points of view, agents sometime confuse the term digital with digitization. To distinguish them, digitization refers to the standardization of processes and is associated with excellence in company/country operations, close monitoring of costs, and imposing strict discipline on the processes of the incorporation of digital technology. In contrast, the term digital has a broader meaning and refers to the set of opportunities offered by the use of digital technology in all companies, countries, areas, and businesses, redesigning the entire value proposal and business model and considering all of the actors involved. Therefore, digital transformation and digital companies or countries require a digital vision, rather than digitization (Ross, 2017).

Regarding this distinction, there are very few business and country leaders with holistic views of DT (Bughin *et al.*, 2018). As Westerman said (Westerman *et al.*, 2019), the most important word in DT is not digital but transformation. Derived from this idea, understanding the meaning of digitalization as the integration of digital technologies among citizens and businesses in daily life through the digitization of everything that can be digitized, could imply falling into the digital trap confusing the term digital as an objective in itself and missing other higher objectives (Finette, 2017). In the business environment, the key point is the use of technology as a catalyst that allows for connecting, increasing and improving business capabilities, citizen and customer experiences and economic efficiency redefining processes and developing new business models through creating and capturing value (Technology Vision, 2017).

Indeed, if it wants to understand digital power, it is necessary to raise the bar knowing its multidimensional influence avoiding simple unidimensional vision. Digitalization allows connection to be transversal, opening the door to a digital ecosystem (Gartner, 2017). In this sense, the ecosystem concept is modelled as a set of elements located within a complex whole in which each niche fulfils a particular function (Rynn, 2007). According to Gartner, a digital ecosystem is an interdependent group of actors (organizations, people, things) sharing standardized digital platforms or protocol to achieve a mutually beneficial purpose. As a result, for leading organizations, countries and cities, digital ecosystem adoption seems to offer enhanced market access and thus is a medium for more rapid innovation and greater productivity growth (Gartner, 2017). The interesting point here is that digital ecosystems allows a more multidimensional approach to the value proposition offered by organizations, corporations, cities or countries, and they go beyond having a unidimensional and unidirectional vision about the reality and the agents involved in it, as Figure 2.9 illustrates.

Figure 2.9 Digital Ecosystem



Source: The author. Framework adapted from Digital Ecosystems (Gartner, 2017)

According to Mckinsey (Atluri *et al.*, 2018), a world of digital ecosystems will be a highly customer and citizen-centric model, in which users can enjoy an end-to-end experience for a wide range of services and products through a single access gateway included in the ecosystem. Digital ecosystems will comprise diverse key players that provide digitally accessed, multi-organizational solutions. The relationship among these members will be commercial or contractual, and the contracts (written, smart contracts, or both) will formally regulate payments or other considerations, such as taxes or other services provided, and the rules governing the provision of and access to ecosystem data. On the other hand, one important thing is that the digital ecosystems writ large can encompass any set of interacting institutions, producers, suppliers, innovators, customers and regulators pursuing a collective outcome, creating value (Jacobides, 2019).

Regarding to this, it should be considered that, public or private organizations in countries or cities, before embarking on digital ecosystem development, should first have a clear idea of what their purpose is, considering first the solving of citizens' problems and, subsequently, using technology to develop these solutions. This order of factors is important and makes a difference between "being digital" and "doing digital" because of its enormous consequences since people who do not contemplate this order can fall into a detrimental digitization focusing more on how to use all of the tech available rather than putting people first or people-centric (Cognizant, 2016).

2.2.1. Digital and Programmable Economy (Blockchain, DLT and Digital Assets)

According to Michael Porter, in terms of tech, it is the uses of the Internet and its network effects rather than tech that ultimately create value (Porter, 2001). In order to reinforce this uses, within the digital environment, it is worth mentioning the concept of programmable economy (PE) in the early phase known as the application programming interface (API). PE, as a pillar of the digital economy building programmable business (Bolumar, 2015), has an edge in mixing the digital and real worlds. The PE concept was introduced by Gartner in 2014 to refer to an intelligent economic system, making possible new exchanges of value, making it a critical mechanisms in order to capitalize business ecosystems opportunities acting like a platform that it can be programmed and therefore customized and adapted to countless needs and niches (Gartner, 2015; Van Alstyne, 2019; Global Consulting Company, 2018).

This exchange of value can be do it among some physical or virtual's endpoints that fit to an edge. According to Graph Theory, the concept of endpoints is defined as a nodes (things or humans with some value) belonging to an edge or relationship of some sort between two or more nodes and it may be tangible or intangible (Diestel, 2017). Thus, connecting valuable endpoints in digital age means to join nodes or entities with some value (virtual or physical) using for it digital tools. Programmable economy looks forward allowing that this endpoints can exchange this value between them by monetizing it in a trusted way.

PE is supported through blockchain or Distributed Ledger Technology (DLT), Internet of Things (IoT), monetization, token economy, smart contracts, artificial intelligence and cryptography supporting new forms of value exchange on new types of markets and new forms of the economy. In this PE, it will be the individuals and smart machines that define value and determine how exchanges will be determined through peer-to-peer transactions involving organizations and even smart machines and agents, allowing for the creation of new business models by combining the physical world with the digital one (Gartner, 2015).

The implications of PE include removing the middleman, imagining new ways of exchanging the value of the tangible and intangible between people and institutions, rethinking new forms of governance relationships, allowing for greater automation by minimizing external oversight, decentralizing the economy and managing information better. One of the greatest characteristics of PE is the possibility of monetizing things and services by redefining the economy and the way in which value is exchanged between intelligent physical or intangible things among several actors, including corporations, citizens, and institutions (Sloan, 2018), as enabled the transformation of the web from the “Internet of information” to an “Internet of value” (Tapscott, 2017).

As a source of trust, PE can expand corporations’, institutions’ and citizens’ degrees of digital transformation, whereby processes and objectives can be shared among all actors. All of these changes are possible because this technology renders the information contained within it immutable, safe, shared and consensual (Harvard Business Review, 2017).

To understand PE, it is necessary to go into detail about blockchain technology. Blockchain is one type of a distributed ledger, and it uses independent computers (referred to as nodes) to record, share and synchronize transactions in their respective electronic ledgers, instead of keeping data centralized as in a traditional ledger (The World Bank, 2018). Blockchain technology is defined as *"a list of irrevocable transaction records, cryptographically signed, shared by all participants in a network, in a peer-to-peer manner”* (Gartner, 2018).

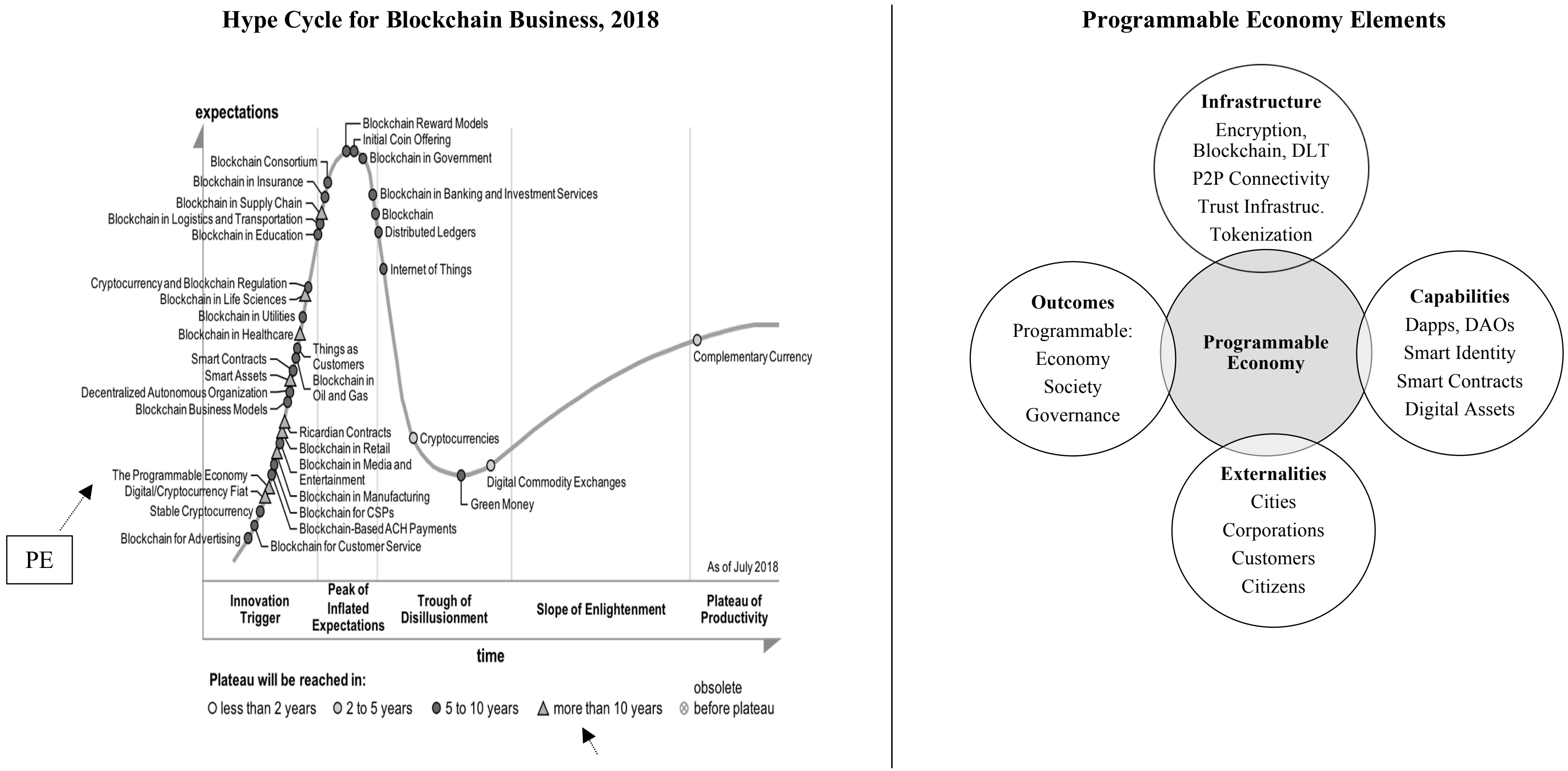
In addition, the token economy and blockchain activate the possibility of deploying the digital asset concept (the digital asset market in the representation of physical or intangible assets), preventing duplication through the generation of smart contracts or protocols that facilitate everything because tokens or units of value can be employed to make payments (Kandaswamy *et al*., 2018). The key differentiation between traditional assets and digital assets by blockchain concerns history, identity and transparency. Anything that exists in a binary format comes with the right to use it, moves around networks with a history that is unaltered and intertwined with the movement itself, while recordation is not optional, and redaction is not possible; in other words, it is much trusted (Muth, 2019).

Indeed, PE by smart contracts or intelligent contracts (Szabo, 1996), facilitate the agreement of individuals, organizations and institutions in such contracts regarding how they want their business or public services to be implemented consistently and automatically, keeping participant interactions recorded transparently at all times. This technology allows for better decision making between people and between machines without human intervention.

Additionally, one of the most important characteristics of PE technology is that it very consistently allows for the reduction of the so-called transaction costs (Coase, 1937) including the costs of organization, negotiation, information monitoring and coordination (Potts *et al*., 2017). PE technology tends to reduce decisions, and many coordination functions could be replaced by software, opening new institutional and corporation possibilities to reduce transactions, control, and monitoring costs and to provide the possibility of achieving more efficient data coordination, become an excellent technology for governance, decentralization and information systems, impacting productivity and organizations' efficiency (Davidson *et al*., 2018). Therefore, organizations and institutions will need to evaluate and adjust their technology portfolios, staffing needs, organizational structures, and product and/or service offerings, as well the way in which they conduct business and interact with vendors, partners, customers and citizens (Pemberton, 2018).

Thus, PE consists a natively smart economy system (Stamford, 2016) and is included in the blockchain technology overview. This phenomenon will emerge over the next decade by 2035 as a highly probable, according to Gartner’s adoption estimation Hype Cycle for Blockchain Business trajectory (Gartner, 2018). This estimation and the amount of elements that make up PE are shown in Figure 2.10.

Figure 2.10 Programmable Economy Trend and Elements



Source: The author. Framework adapted from The Reality of Blockchain (Gartner, 2018)

2.2.2. Digital Economy

The core of the digital economy according to Bukht (Bukht *et al*., 2018) is defined as a part of economic output derived solely or primary from digital technologies with a business model based on digital goods or services. It is estimated to make up approximately 5% of global Gross Domestic Product (GDP) and 3% of global employment and its effect over the economy has the potential to generate immense value with around $100 trillion at stake for industry and society over the next decade. Although the vast majority of this value is likely to accrue to society rather than business, unfortunately it is no means guaranteed that the first will be captured (Martin *et al*., 2018).

The impact of the digital economy should be understood as the disruption of existing processes, reconfiguring consumer behaviour, business interactions and their own models while driving economic growth by increasing productivity per hour worked, reducing the cost of transactions and facilitating access to global markets (Dahlman *et al*., 2016). According to World Economic Forum (WEF) the digital economy has a special intensity in emerging countries growing by between 15% and 25% per year (World Economic Forum, 2015).

Actually, countries, citizens and businesses are experiencing daily base digital economy effects (amount of information, connection, automation, and digitalization), becoming a source of competitive advantage for countries and important driving and restructuring force in the current economy (Manning *et al*., 2016; Brynjolfsson *et al*., 2012). Digital economy reduces the number of intermediaries, enabling greater transparency and making immediacy possible with zero marginal costs changing competitiveness rules (Gill *et al*., 2017).

According to Van Ark, a limited number of countries and industries have made a complete transition to the digital economy, and few are experiencing advances in their productivity indicators, suggesting that they are in the "installation" phase, a long period during which new technologies emerge and advance, driven by new ways of doing things and establishing new practices more than in the "deployment" phase, in which technology plays out as a true General Purpose Technology (GPT) in all its aspects and agents by pervasive use and widespread adaptation of technology in multiple applications, and substantial real cost decreases, leading to lower prices, as well as market scale for new products and services transforming value (Van Ark, 2016).

Digital phenomena, as a source of competitiveness for countries affect that all of them pursue high levels of digital metrics (Gill *et al*., 2017; Chakravorti *et al*., 2017; European Commission, 2017). To determine and measure this performance, there are some institutions and private organizations that generate some metrics such Digital Economy and Society Index (DESI) (European Commission, 2017) or Digital Planet Model (Chakravorti *et al*., 2017), among others.

2.2.3. Digital Smart Cities

Currently, 55% of the world's population lives in urban areas. Far from stagnating and looking beyond, it is expected that, by 2050, the number of urbanites will reach 68% of the total world population (The World Bank, 2018). This enormous pressure for urban space efficiency is opening the way towards the incorporation of ICT in Smart Cities (SC), and a balance must be considered between the technological aspects and human capital (Perera *et al*., 2014; Gil-García *et al*., 2016).

Current reality leads to conclude that there is no common definition regarding the SC concept; however, there would be some consensus that these concepts are characterized by sharp use of ICT, although the deployment of these technologies does not necessarily guarantee a better city (Harrison *et al*., 2011). It is not only about maximizing city digitization. It should be a step beyond the pure connectivity of the SC 1.0 models and should move towards optimization in decision-making formulas or SC 2.0 that offers quality of life for citizens and visitors based on a greater collaborative and consultative effort (Ottawa, 2017).

From a technological outlook, the literature review notes two major ICT roles in cities. On the one hand, there would be the technological role of improving productivity through the automation of routines and processes favouring better decision making. On the other hand, a body of studies would appear to place the focus on the human capital role (Perera *et al*., 2014; Gil-García *et al*., 2016). In this way and depending on the application and importance of ICT, two domains emerge: "hard" (with a greater preponderance of the application of new technologies) and "soft", in which the ICT role is more limited (with a greater preponderance of education, social inclusion, governance, economy, and innovation), (Neirotti *et al*., 2013).

There is no doubt that the deployment of ICT in cities is having a large impact on how cities are planned and organized (Arroyo-Cañada *et al*., 2017) and, more importantly, how the networks are established between the subjects and objects, from social aspects to economic ones: mobility, connectivity, consumers, commerce, taxes, resources, management, and collaboration (Batty *et al*., 2012). According to Bruneckiene, common characteristics of a smart economy in digital SC, they are a set of innovation economy, learning economy, digital economy, competitive economy, green economy, social economy and network economy (Bruneckiene *et al*., 2014).

In addition, for the most advanced cities, the SC 2.0 phase allows a higher quality of life for citizens and visitors, greater economic competitiveness and accepts the possibility to deploy new sustainability and environmental models (Ottawa, 2017; Eggers *et al*., 2018). Regarding to this issue, despite technology playing an important role in the future as a "hard" factor, it is important to believe that there are other "soft" factors, to be considered in cities because one of the fundamental objectives of technology is to improve quality of life (Cooray *et al*., 2017; Zanella *et al*., 2014, Giudice *et al*., 2011). So, in some cities, all of these changes are focusing on creating the best places for sustainable life, reinforcing in them the term "digital smart eco-city". In these places, intelligent technologies are deployed, promising comfortable SC while protecting the environment and driving sustainability by an optimal combination of resources, technology and human factors (Verfürth, 2018).

Equally, related to digital implication over SC, blockchain/DLT application allows for the appearance of so-called digital crypto-cities, transforming how cities coordinate and organize. A crypto-city is one that strives to open and decentralize city data using crypto-economic tools and technology (Potts *et al*., 2017). Blockchain technology is a remarkably transparent and decentralized way of registering lists and transactions, and it will have a large impact in many areas, including cities. In particular, its deployment in the sphere of the public sector and SC will affect a large number of activities. According to the European Parliament, blockchain technologies could provide new tools to reduce fraud, avoid errors, cut operating costs, boost productivity, improve compliance and improve accounting (Boucher *et al*., 2017).

2.3. Sustainability, Reinforcement and Brand Activism

Currently, in the business, economic and management spheres at the level of countries, cities, organizations, institutions, corporations, citizens and consumers worldwide, there is one aspect that actually pressures all of them increasingly every day, which is sustainability. This term was defined in 1987 by United Nations Brundtand Commission as *"meeting the needs of the present without compromising the ability of future generations to meet own needs"* (World Commission on Environment and Development, 1987).

Concerning to this, one of the most threat over sustainability, in order to ensure development today does not negatively affect future generation, is climate change. According to Winston, dangerous climate change is the greatest threat that humanity has ever faced (Winston, 2019), and this challenge is not easy to solve individually.

Regarding to the importance of sustainability, United Nations includes the urgency of this term in the 17 Sustainable Developments Goals (SDGs) 2030 Agenda committing to achieve sustainable development in three dimensions, economic, social and environmental in a balanced and integrated manner (United Nations, 2019). This agenda has mention specifically that governments, international organizations, the business sector and other non-state actors and individuals must contribute to changing unsustainable consumption and production patterns and recognise that economics and social development depends on the sustainable management of the planet and the cities.

In order to find solutions related to this and manage this issues, the sustainability as a value and as a source of competitiveness is having substantial increase in the academic and business fields such as marketing, financial, management, economics, innovation, technology, or social corporate responsibility and so on, and is shared by many individuals, organizations and institutions who demonstrate the importance of this value including it in their present and future strategic plans (Elkington, 2004; United Kingdom Green Building Council, 2018; Belz *et al*., 2009; Kotler *et al*., 2018). In this task, among the most important challenges is how to use digital and ICT advantages to meet this challenge, since, according to World Economic Forum digital innovation, PE and digital value to society (DVS) can drive SDGs progress in the next decade (Martin *et al*., 2018; Dao, 2018).

Two interesting approaches to the role of technology in economics and sustainability have been developed; substitutability (Solow, 1993) and the Steady-State Economy (SSE) (Czech *et al*., 2004). Solow's idea of sustainability is founded on technology being able to create high degrees of substitutability between one resource and another. In contrast, Czech and Daly (Czech *et al*., 2004) defended the idea that many of the resources that nature provides cannot be replaced by products or services made by human beings. Therefore, the neoclassical economic view sees growth as continuous expansion, while the SSE model believes that the economy must be in permanent equilibrium with the ecosystem in which it operates (Ashford, *et al*., 2011).

Tomorrow's SC requires facing this dilemma, regarding whether the natural goods that affect an SC in a broad sense can be substituted with goods made by humans through technology or whether said technology can become a complement to promote the balance of the ecosystem. As mentioned before, these sustainability issues are causing some city managers to include some initiatives such as the "digital smart eco-city", promising that SC grow while determining the balance between progressive programmes and environmental protection (Verfürth, 2018).

From other standpoint, according to Giddings, sustainable development should be an integrated approach considering environmental, political, social and economic factors (Giddings *et al*., 2002). From the point of view of economic and business organizations, the link between sustainability activities and finance enhances performance as this link grows (Heyns, 2012), despite individual businesses not perceiving this link as very clear since the internal cost of sustainability is easily measurable, while its financial value and its effects are divided into different parts of the business, and its value created is sometimes indirect or unequal.

In this sense and according to United Kingdom Green Building Council, the value created in the field of business would be any variable or factor that can be influenced, measured, managed and controlled and, in doing so, affect the value of the organization by one or more means, reducing risk and increasing profitability. For organizations, this value created is not permanent; rather, it changes over time, and indeed, sustainability will be one of the most important business value-created drivers because its implementation could be translated into organizational advantages, such as cost savings, talent attraction and retention, customer attraction and satisfaction, brand and reputation, licence to operate, resilience, access to capital, innovation, productivity, quality and value of assets (United Kingdom Green Building Council, 2018).

Focusing on social aspects, any contribution to resolving sustainability concerns should include human features (Giddings *et al*., 2002) and particularly motivational features (Bell *et al*., 2013), among others. Related to this point, one of the ways of providing motivation is through the application of reinforcement theory, also known as learning theory (Skinner, 1953). Skinner proposed that the administrator need only understand the relationship between behaviours and their consequences to create conditions that encourage desirable behaviours and discourage undesirable ones. Behaviours are learned through positive or negative consequences. Reinforcement theory is widely used in organizations as an instrument to increase or decrease employees' behaviours and as a key factor to motivate staff (Wei *et al*., 2014). This appreciation could be used in city management to motivate citizens and to reinforce them in or dissuade them from their unsustainable habits. Regarding this topic, currently several countries are testing citizen's incentive systems for different purposes such as increasing recycling rates or diminish urban congestion in England (Harder et al., 2007; Shaw et al., 2008) or improving citizens' behaviour in China through Social Credit System (Xu et al., 2018) among other.

Moving on to sustainability marketing aspects, corporations and organizations are undergoing a transformation from corporate social responsibility to engaging in “brand activism” because the measures undertaken by governments and online institutions to reverse unsustainability are insufficient (Kotler *et al*., 2018).

The “brand activism” was presented by Kotler and Sarkar and includes the set of efforts made by corporations with the desire to promote sustainability and improvements in society (Kotler *et al*., 2018). As society becomes aware of the environmental impact of the products and services that it consumes, consumers and citizens are accepting responsibility for their purchases and lifestyles. Consumers increasingly expect not only the company but also the whole supply chain to be sustainable (Belz *et al*., 2009), and this expectation constitutes a good opportunity for companies.

According to Sheffi (Sheffi, 2018), there are four reasons that company managers should embrace sustainability because consumers and investors consider it is, important, reduces costs, younger people are more aware of the aspects of sustainability and the reduction of the resources available. Recent studies have confirmed that consumers (Millennials, Generation Z and X) increasingly demand more sustainability in the products that they buy (Nielsen, 2018). Considering this, corporations and organizations that implement a progressive policy of brand activism will also experience a significant impact on their sales, service and customer or citizen experience (Kotler *et al*., 2018) and they will play a large sustainability role in SC and citizen's daily base.

Chapter 3

Beyond Digital Transformation Race

Beyond Digital Transformation Race

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Abstract

Economies want to be digital. Considering this desire, some countries are involved in an obsessive digital race, wanting to gain in short-term stages without realizing that they are losing progress in long-term positions as a result of having an unclear understanding of digital transformation (DT) and its hidden implications. This work aims to discover the imbalances occurring among countries' performances between digital levels and their Gross Value Added (GVA) over time. The research concludes that the actual spectrum of digital analysis should also reinforce non-tech variables, and public and private agents should consider them in their programmes. Consistent digital transformation advances can be obtained only when they are treated as ecosystem phenomena.

Keywords: Digital Transformation, Digital Ecosystem, Innovation, Competitive, Employee Engagement.

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3.1. Introduction

Digital technology lives its particular "momentum". Many countries are pushing digital strategy variables to create a more promising future for their economies and for citizens' wellbeing. However, in this race, countries and agents should not lose sight of digital vectors being one more factor within a complex economic environment full of uncertainty, velocity and dynamicity.

The definition of digital is sometimes blurred. The literature review indicated that digital means all forms and uses of information and technology electronically manageable through the transmission of signals that transfer information through a series of coded impulses that represent 1s and 0s as a binary code (Gartner, 2015). For other authors, digital means allow people to connect to devices and physical objects anywhere in an instant and at a low cost (Bughin *et al.*, 2018). This alteration affects all material objects transforming everything from the tangible side to the intangible side, changing the economic spectrum and reflecting digital phenomena more than a purely technological mode.

This transformation from atoms to bits should not be understood exclusively as replacement. Rather, it is that countries, companies, institutions and their citizens should seek the best possible combination of physical and digital resources to be efficient, to compete, to innovate, to advance and to achieve news way of doing things. The idea that digital technology is simply replacing the analogue world with a digital world remains far away. Rather, using both resources, countries and agents should understand their relationships and the connections between them that are derived to create innovative combinations of them (McDonald *et al.*, 2012).

Actually, countries, citizens and businesses are experiencing daily base digital effects. Incessant digital density, as a measure of the amount of information, connection, automation, and digitalization, is growing exponentially worldwide, becoming a source of competitive advantage for countries (Manning *et al.*, 2016). However, is any connection or automatization valid to say that a country or agent is digital? From the economic and business perspectives, the key point is to know what type of connections produce some value added that improve country magnitudes.

In this sense, for many countries, the digital miracle is spreading as an isolated priority without considering that digital factors act more as a transversal, adherent and multiplicator element over other core issues (Knickrehm *et al.*, 2016). This consideration is a consequence of a lack of vision of digitalization; in other words, it is a type of obsession to reach the best positions in countries via digital competition but missing the global context scan.

Recent studies carried out by McKinsey (Bughin *et al*., 2018) indicated that there are very few business leaders with a holistic view of the term digital as a mere concept related to technology and the meaning of digitalization as the integration of digital technologies into citizens' and businesses' daily lives through the digitization of everything that can be digitized (Finette, 2017). In the business environment, the key point is the use of technology as a catalyst that allows for increasing and improving business capabilities, citizens and customer experiences, economy efficiency, rethinking of processes and the development of new business models (Accenture, 2017). It is important to emphasize that, if countries want to win the digital race, they should know their economic drivers, determining the best connection between technological and social issues, opening up their view and having them see in an extensive way what is happening with the bases of their economy as a whole. Thus, they should understand how the digital factor could accelerate progress variables in a consistent and integrative manner.

Indeed, according to Brynjolfsson, digital technologies are among the most important forces driving the current economy and a major cause of business restructuring (Brynjolfsson *et al*., 2012). In this sense, what large companies and countries are doing now, beyond having a specific digital strategy, are digitizing their fundamentals rather than creating new ones digitizing their culture, capabilities, innovation, competitiveness, and organization and forgetting key aspects, such as that the digital economy reduces the number of intermediaries, enables greater transparency, makes immediacy possible, favours zero marginal costs and changes competitiveness rules (Gill *et al*., 2017). In this context, organizations will need to bear in mind that digital technology is a facilitator of transversal connection and a multiplier of economics and the management of country factors, more than a single and exclusive input (Knickrehm *et al*., 2016). Related to this points, countries should use digital input as a transversal force to reinforce their productivity and value added variables while avoiding using exclusively the best digital economy rankings.

Just as digital performance control over economic global frameworks and therefore the pursuit of digital consistency are crucial tasks, countries should also be vigilant in their digital strategies. According to Rogers (Rogers, 2016), digital strategy must serve five domains: 1 - competence inside and outside; 2 - data, converting the enormous amount of data that countries and cities have into valuable information; 3 - innovation, the ways in which companies and countries innovate; 4 - clients/citizens, by increasing the dynamic participation as a critical driver of business; and 5 - value, to determine the next source of value for the client/worker/citizen.

Therefore, considering the above aspects, in this period of digital disruption, countries should rethink more broadly their DT such as an ecosystem (Weill *et al.*, 2015) considering that according to Van Ark, DT has an installation stage (focus on tech elements) first and second the deployment stage, where countries have overcome the first stage and have started to combine and exchange the endpoints generating value (Van Ark, 2016).

The objective of this exploratory research is to show, from a qualitative point of view, how European Union (EU28) countries are implementing their digital strategies and to understand how DT could advance value added in countries. The key is to show the different options that countries are using in their digital strategies, determining whether countries' digital phenomena are seen as one shot incorporating and increasing the use of digital technology exclusively and forgetting the remaining economic drivers or, in contrast, whether it is managed from an ecosystem approach, attaching to the digital vector while energizing other economic and management vectors and acting as a whole in seeking real symmetry between digital and productivity aspects such as GVA.

This paper is organized as follows. In Section 2, the digital momentum is exposed. In Section 3, the digital ecosystem is presented, while Section 4 the methodology is exposed and in Section 5 results are showing. Finally, Section 6 summarizes the most important conclusions and limitations of this paper.

3.2. Digital Momentum

According to European Commission, Digital phenomena is a source of competitiveness for countries; thus, all countries pursue high levels of digital metrics. To determine this performance, EU28 countries use the Digital Economy and Society Index (DESI) (European Commission, 2017). DESI is a composite index that summarizes the relevant signs on digital performance and tracks the evolution of EU28 members in digital competitiveness. The notion of digital competitiveness is central for countries, institutions, entrepreneurs and citizens.

In contrast, Digital Planet Model (Chakravorti et al., 2017), defends that the competitiveness of a country, in terms of the digital economy, is a function of two factors: on the one hand, what the current situation is of national digitalization and, on the other hand, what the growth in this variable is over time, that is, what the trajectory is in this process. Their relation allows to calculate "digital momentum" as a measure which countries are growing their digital phenomena "relatively fast" or "relatively slow" over time with respect to the rest of the countries analysed, in others words as a current indicator of their digital imbalance and expected trajectory.

3.3. Digital Ecosystem

As it mentioned before, knowing the state of each EU28 country's digital force should be interesting in attaining a good vision about digital performance over time. However, to have a broader vision of what is truly happening in each country, it is necessary to incorporate and compare more indices to see a broader landscape and to distinguish whether a country is in digitization mode or in digital mode (Ross, 2017). This difference is basic.

According to Ross (Ross, 2017), the term digitization refers to the standardization of processes and is associated with excellence in operations, close cost monitoring, and the imposing of strict discipline on processes. In contrast, the term digital has a broader spectrum and refers to the set of opportunities offered by the use of digital technology in all companies/countries, redesigning the entire value proposal and business model and considering all of the actors involved. According to Knickrehm, the broad-based application of digital technologies including the enabling environment, company behaviour such as employees engagement and consumer attitudes, matters in driving productivity gains (Knickrehm *et al.*, 2016). Therefore, DT and digital companies and countries require a digital vision rather than digitization because digital technology is a multiplicator of value proposal going beyond considering it a technologically isolated factor to a critical factor among other ingredients, all of which are included in the country's value added, such as innovation, competitiveness or employee engagement, among others, all of which act as an ecosystem (European Commission, 2017; Knickrehm *et al.*, 2016).

In this sense, the ecosystem concept is not conceived as a set of similar elements, but it is modelled as a set of functional niches, a set of elements located within a complex whole in which each niche fulfils a particular function (Rynn, 2007). The ecosystem point of view applied to the digital country environment leads it to conclude that the use of technology by countries is a niche within a set of functional roles (Gartner, 2017), such as competitive environments, innovation practices or workers engagement, among other elements. These factors, together leading the digital force establishing a digital ecosystem (DE). Its results could have substantial impact on the Gross Value Added (GVA) that each country generates.

Regarding this idea and to be able to compile this DE, the following forces are considered a transcendental economic vectors that have a great impact on country development such as digitalization, innovation, competitiveness and employee engagement (European Commission, 2017; Global Innovation Index, 2017; World Economic Forum, 2017). Fortunately, these force are estimated under some indices and they developed by prestigious institutions on an annual or biannual basis worldwide or at the European level -- with the exception of employee engagement, which is not addressed at the European level. They are as follows:

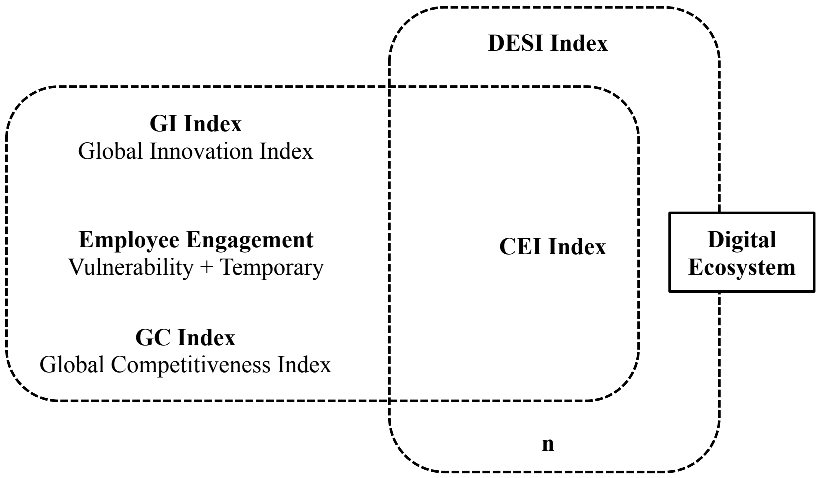
o Digital Economy and Society index (DESI): The Index of economy and digital society is a composite index that summarizes relevant indicators about the digital performance of Europe and tracks the evolution of EU member states in digital competitiveness (European Commission, 2017).

- Global Innovation Index (GII): The Global Innovation Index covers 141 economies worldwide and uses 79 indicators across a broad range of topics. Therefore, the GII presents a rich set of data to identify and analyse global innovation trends (Global Innovation Index, 2017)
- Global Competitive Index (GCI): The Global Competitiveness Index attempts to quantify the impact of a series of key factors that contribute to creating the conditions for competitiveness, with a particular focus on the macroeconomic environment, the quality of the country's institutions and the state of the country's technology and support infrastructure (World Economic Forum, 2017).
- Employees Engagement Index (EENG) or employee commitment level: At the level of the European Union, this indicator is not available. For this reason, an approximate index has been built considering several factors that would affect this vector. Regarding the literature review, good employment strategies involve investing in employees. This investment can help organizations reduce their costs, increase labour productivity and ensure that employees are familiar with the products involved in customers' experience (Zeynep, 2013). In addition, employee commitment is correlated with decreases in absenteeism, turnover, accidents and defects while also being correlated with increases in customer service, productivity, sales and profits (Kruse, 2014). Cumulative effect has an impact on the country economy that allows for creating a proxy index, which includes these concepts through the available index: 1 - the level of employee vulnerability, which refers to unpaid family workers and self-employed workers as a percentage of total employment (World Bank, 2017), and 2 - the level of temporary employment published by Eurostat (Eurostat, 2017). Through these data a simulated index of employee engagement has been built.

To facilitate the structure of the DE, a Digital Ecosystem Model (DEM) has been built described in Figure 3.1. DEM is modelled as a digital ecosystem, a set of functional niches and roles, a set of elements located within a complex whole in which each niche fulfils a particular function sharing standardized digital platforms or network (Rynn, 2007; Gartner, 2017).

The values of the GII, GCI and EENG are added in a single index called the Competitive, Engagement and Innovation (CEI) index. The interrelationships between the DESI and CEI index constitute the main axes of the Digital Ecosystem Model (DEM). The variable “n” included in the DEM, refers to the set of other variables not included in this model and that would affect the digital ecosystem.

Figure 3.1 Digital Ecosystem Model (DEM)



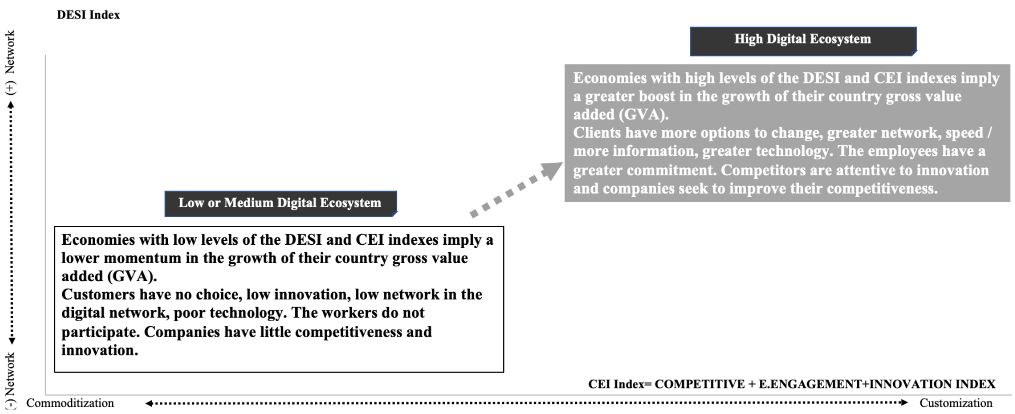
Source: The author

Once the DEM has been established, the next step is to understand from a qualitative point of view the impact that this DE has on EU28 countries’ GVA over time.

GVA is a measure of producers’ and industries’ productivity (OECD, 2001). According the Eurostat definition, GVA is defined as output value at basic prices minus intermediate consumption valued at purchasers' prices. GVA is calculated before the consumption of fixed capital. It is available according to a breakdown of 10 main economic activities according to NACE Rev. 2 -Statistical Classification of Economic Activities in the European Community- (Eurostat, 2017).

To determine qualitative relationships between countries’ GVA performance and their DE, Digital Ecosystem Equation (DEE) is used in Figure 3.2, inspired by the Manning model (Manning *et al.*, 2016), which relates positively relationship between the customer and citizen experience, innovation and competitive with the level of income generated by a company/country. Using digitalization and CEI indices (competitiveness, innovation and engagement indices), a relationship of these indicators with the level of countries' GVA has been assumed.

Figure 3.2 Digital Ecosystem Equation (DEE)



Source: The author through Manning Model (Manning *et al.*, 2016)

According to the DEE explanation, a relationship between GVA and the digital ecosystem has been exposed. Thus, crossing these two indices (DESI, CIE) for each country allows for allocating countries' ecosystem performances and could be compared with their GVA performance. Regarding this point, the following hypotheses are proposed:

H_1: Given a country sign value of the $DESI^+$ with respect to the EU28 average, there is a greater probability of having GVA^+ from its digital ecosystem indices $DESI^+$and CEI^+ with respect to the EU28 average than having it come from the $DESI^+$ index in isolated mode.

H_2: Given a country sign value of the $DESI^-$with respect to the EU28 average, there is a greater probability of having GVA^- from its digital ecosystem indices $DESI^-$and CEI^- with respect to the EU28 average than having it come from its $DESI^-$ index in isolated mode.

3.4. Methodology

With the idea of determining the model's validity and calculating its overall probabilities that the consistency about DE in a country means good performance about GVA, considering the knowledge where an event B occurred can be deducted from the probabilities of an event A, the Bayes Theorem (Thomas Bayes, 1702-1761) will be used. To explore this topic, it is relevant to mention that the digital ecosystem does not aim to find the causality or any correlation value with the country Gross Value Added. It is about exploring qualitatively sign direction (positive or negative) using non-parametric probabilities and the best equilibrium between CEI and DESI indices belonging to the digital ecosystem to determine the digital ecosystem balance sheet with the greatest probability to have positive or negative GVA sign performance related to each country. On the other hand, to do this and in order to understand what is going on about digital transformation by country during a period of time, Momentum Score has been calculated through Scaled Momentum Score (SMS) and the construction of Competitive Engagement Innovation index proxy are been calculated (Chakravorti *et al.*, 2017). The reason why this methodology is used is that there are no studies that use conditional probability to know the countries´ GVA performance related to their level of digitalization.

3.4.1. Momentum Score

Momentum Scores are generated using the Compound Annual Growth Rate (CAGR) formula. According to Corporate Finance Institute (Corporate Finance Institute, 2017), CAGR is often used to measure and compare the past performance of values or to project their expected future. The CAGR formula is as follows:

$$CAGR = \left(\frac{Ending\ Value}{Beginning\ Value}\right)^{\left(\frac{1}{\#\ of\ years}\right)} - 1$$

This value represents the mean annual growth rate of the scores over a period of time and it has been used over the DESI index during the period 2014-2017.

After calculating the rates using the CAGR formula, it has been scaled by Scaled Momentum Score (SMS). The scale has been constructed based on the percentage of CAGR on a scale of 20 points (-10 to 10). This means momentum scores, like the final index scores, are relative scores. As such, they measure which countries are growing “relatively fast” or “relatively slow.” (Chakravorti *et al*., 2017), and its formula is as follows:

$$SMS = \left(\left(\frac{20\ x\ CAGR\ value - Min\ CAGR\ value\ in\ data\ set}{Max\ CAGR\ in\ data\ set - Min\ CAGR\ in\ data\ set}\right)\right) - 10$$

Through CAGR and SMS, digital momentum relationship has been represented in a graph.

3.4.2. CEI Index

The construction of the Competitive Engagement Innovation (CEI) Index is an aggregation index of Global Competitive Index, Global Innovation Index and Employees Engagement Index and its formula is explained in Table 3.1:

Table 3.1 CEI Index Explanation

Index	Range	Source
GCI: Global Competitive Index	0-100	-Global Competitiveness Report, period 2016 to 2017, (World Economic Forum, 2017).
GII: Global Innovation Index	0-100	-The Global Innovation Index Report, period 2016 to 2017 (Globalinnovationindex, 2017)
EENG: Employees Engagement Index= 100 -(Workers Vulnerability Index + Temporary Employment Index)	0-100	-Eurostat (Eurostat, 2017), and The World Bank (The World Bank, 2017) period 2014 to 2015.
CEI Index = GCI+GII+EENG	0-300	
Source: The author		

According to The World Bank (TWB) Workers Vulnerability Index refers to unpaid family workers and self-employed workers as a percentage of total employment (The World Bank, 2017). On the other hand, according to Eurostat (Eurostat, 2017), Temporary Employment Index is considered as, employment is temporary if the employer and the employee agree that the purpose is determined by objective conditions, such as a specific date, the completion of a task or the return of another employee who has been temporarily replaced (usually indicated in a contract of employment or work of limited duration). The typical cases are: (a) people with seasonal employment; (b) people hired by an agency or job board and hired by a third party to perform a specific task (unless there is a written work contract of unlimited duration); and (c) people with specific training contracts. The indicator is based on the EU survey of the labour force (Eurostat, 2017).

3.4.3. Bayes' Theorem

In order to understand why it is used Bayes' Theorem, it is relevant to mention that this study does not aim to find the causality or correlation between values performance. Regarding this, conditioned probability refers to the probability of occurrence of a hypothesis, depending on the presence of new evidence and is it used to represent the relationship between what is known and what can be revealed in order to improve decision making (Berenson, 1992). The Bayes theorem (Thomas Bayes, 1702-1761) is a mathematical rule that allows researchers to combine new data with their existing knowledge where an event B occurred can be deducted from the probabilities of an event A. According to Corporate Finance Institute (Corporate Finance Institute, 2018), the calculation of conditional probabilities is:

let $A_1, A_2, \dots, A_k$ be a collection of k mutually exclusive and exhaustive events with prior probabilities $P(A_i)$, (i=1,…, k). Then, for any other event B for which $P(B) > 0$, the posterior probability of A_j given that B has occurred is as follows:

$$P(A_j/B) = \frac{P\ (A_j \cap B)}{P(B)} = \frac{P(B/A_j)\, P(A_j)}{\sum_{i=1}^{n} P(B/A_i)\, P(A_i)}\quad j = 1, \dots, k$$

Where,

$P(A_j/B)$ is the probability of event A_j occurring given event B has occurred.

$P(B/A_j)$ is the probability of event B occurring, given event A_j has occurred.

$P(A_j)$ is the probability of event A_j

$P(B)$ is the probability of event B

Note that events $A_j$and B are independent events (i.e., the probability of the outcome of event A_j does not depend on the outcome of event B).

This conditional probabilities methodology has been used over GVA, DESI and CEI indices for each EU28 country.

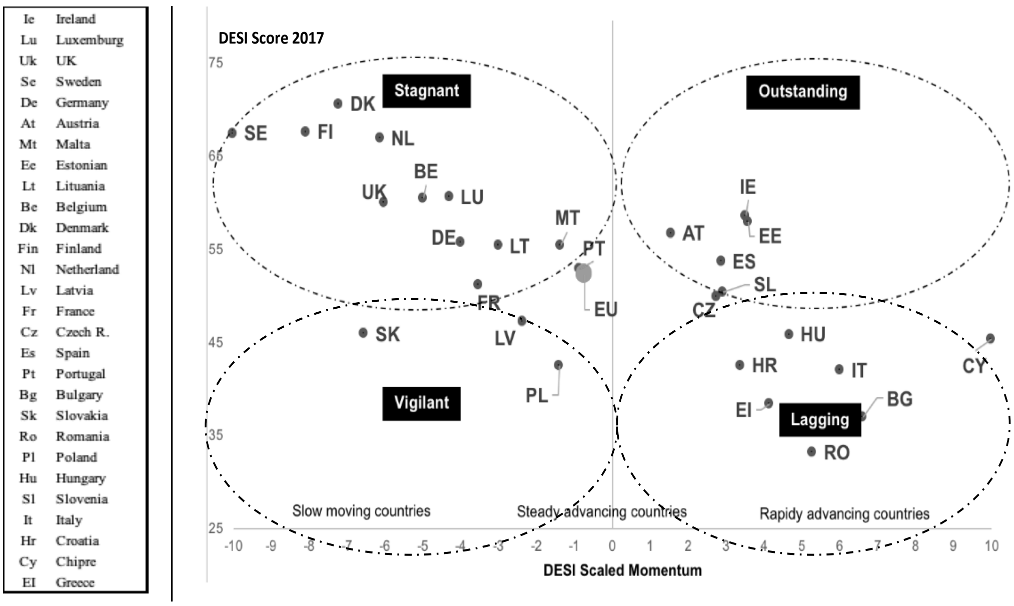
3.5. Results

3.5.1. Digital Ecosystem Imbalance

According to the methodology mentioned above, some results have been obtained:

First, through EU28 countries, the concept of "digital momentum" as an indicator of the digital future of each country and its future potential has been used. To do so, it has been crossed the actual digital position of each country on the ordinate axis with the DESI 2017 indicator (state of digital economy), while on the abscissa axis, it has been included the trajectory of this, that is, the evolution of the indicator Compound Annual Growth Rate (CAGR) over a period of time from 2014 to 2017 on a scale ranging from -10 to 10 (SMS). This representation allowed to classify the EU28 countries into four different stages: Stagnant, Vigilant, Outstanding and Lagging. All of this information is described in Figure 3.3

Figure 3.3 Digital Momentum 2014-2017 (EU28)



Source: The author through DESI Index

The fundamental characteristics of each digital momentum stage can be summarized as follows:

- o Stagnant: Countries with a high DESI but with low DESI scaled momentum. It could be said that they have the need to reinvent themselves and increase innovation.
- o Vigilant: Countries with digitalization opportunities due to their low DESI and low DESI scaled momentum. Possible causes would be the restrictions of their institutions and the lack of consumer sophistication.
- o Outstanding: Countries with an advanced state of digitalization, high DESI and great DESI scaled momentum or speed of growth of the indicator. They require an increase in their levels of innovation and need to create new demand.
- o Lagging: Countries with low DESI but with high DESI scaled momentum due to possible infrastructure deficits and low institutional quality.

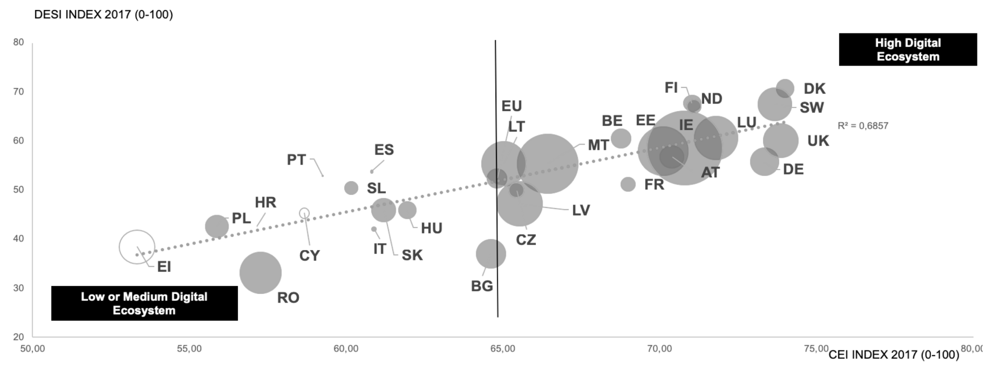
It can be clearly seen in the case of Spain, positioned in the “Outstanding” digital momentum stadium, which means that it has a DESI level above the EU28 average and grows more rapidly than the European average. Observing the results, in terms of actual and future digital performance, the position of this country is very satisfactory. However, in what contextual circumstances is this digitalization occurring and is it increasing the country’s value added?

To answer this question, it should also be known what the performance levels of other indices are that also have a large impact on the country’s economy. Deep footprint value-added forces would be their innovation, including competitiveness or employee engagement performance, among others. Therefore, where the ecosystem concept begins to take relevance is in adding other vectors in, addition to digital transformation itself such as variables mentioned above, all of which act as a part of the whole affecting this final result of a country’s GVA.

Second, the Digital Ecosystem Equation has been developed. It traits incorporate a set of variables beyond the purely technological ones. To calibrate countries’ DEE, Figure 3.4 was generated. The vertical axis indicates the 2017 DESI index, and the horizontal axis indicates the 2017

CEI index. The size of the bubbles indicates the value of GVA CAGR performance from 2010 to 2016 (dark positive/transparent negative).

Figure 3.4 DEE Equation (DESI and CEI Indices vs GVA CAGR 2010-2016)



Source: The author through DESI 2017, CEI 2017 and GVA CAGR 2010-2017

It can be observed that during 2017, most of the countries that have positive performances indices are in the upper right quadrant (high DE), indicating that balanced development of all of the indicators (DESI and CEI) leads to good growth of their GVA, while in the lower left quadrant (low or medium DE) are those countries with significant imbalances and worse performance indices with poor GVA levels in general.

Third and deeper, based on the DEE and DEM explained above, each country was classified according to better/worse DE development (positive or negative CEI, DESI values with respect to the EU28 average). The outcomes of each country are shown in Table 3.2.

Table 3.2 Better / Worse Digital Ecosystem Development

Digital Ecosystem	Country		2017 B/W CEI	2017 B/W DESI	2010-16 B/W CAGR GVA	2017 B/W GCI	2015 B/W EENG	2017 B/W GII
High	Ie	Ireland	17,96	6,17	6,62	5,59	4,13	8,25
	LU	Luxemburg	20,95	8,26	2,84	5,88	8,53	6,55
	UK	UK	27,13	7,68	1,74	10,02	6,07	11,05
	Se	Sweden	26,55	15,11	1,61	10,59	2,02	13,95
	DE	Germany	25,57	3,39	0,95	11,16	5,87	8,55
	AT	Austria	16,71	4,38	0,44	6,16	7,31	3,25
	MT	Malta	4,84	3,02	4,88	-3,84	7,94	0,75
	EE	Estonian	15,91	5,60	3,52	-0,12	14,99	1,05
	Lt	Lituania	0,66	3,00	3,01	-2,70	12,02	-8,65
	Be	Belgium	11,85	8,18	0,01	6,59	5,22	0,05
	Dk	Denmark	27,55	18,30	-0,14	8,02	10,69	8,85
	Fin	Finland	18,65	15,30	-0,31	9,30	0,71	8,65
	Nl	Netherland	18,79	14,62	-0,64	11,16	-5,91	13,55
Medium	LV	Latvia	2,10	-5,18	3,06	-4,84	12,20	-5,25
	FR	France	12,51	-1,17	-0,72	5,88	2,29	4,35
	Cz	Czech R.	1,85	-2,41	-0,51	-0,98	1,69	1,15
	Es	Spain	-12,02	1,35	-2,00	-1,55	-9,41	-1,05
	Pt	Portugal	-16,70	0,50	-2,23	-4,41	-8,53	-3,75
Low	Bg	Bulgary	-0,59	-15,35	1,08	-4,98	11,45	-7,05
	Sk	Slovakia	-10,83	-6,48	0,51	-7,27	2,90	-6,45
	Ro	Promania	-22,64	-19,21	2,64	-6,98	-5,00	-10,65
	Pl	Poland	-26,83	-9,82	-0,36	-3,27	-15,70	-7,85
	Hu	Hungary	-8,62	-6,51	-0,20	-8,41	7,95	-8,15
	Sl	Slovenia	-14,00	-1,93	-0,81	-5,70	-4,24	-4,05
	It	Italy	-11,75	-10,32	-1,77	-4,12	-4,77	-2,85
	Hr	Croatia	-22,98	-9,80	-2,46	-9,12	-3,80	-10,05
	CY	Chipre	-18,46	-7,08	-3,75	-4,70	-3,05	-4,41
	El	Greece	-34,50	-13,94	-6,71	-12,17	-11,05	-6,03
	EU28		0,00	0,00	0,00	0,00	0,00	0,00
	EU28 Index value		194,47	52,4	2,42	68,41	76,21	49,85

High= CEI Index > 0 & DESI Index >0
Medium= CEI Index >0 & DESI Index <0 or CEI Index <0 & DESI Index >0
Low= CEI Index<0 & DESI Index <0
EU28: CEI Index max 300 Min 0. Index GII, GCI, EE (max 100 Min 0)

Source: The author through DESI 2017, CEI 2017 and GVA CAGR 2010-2016

Three groups were established according to the digital ecosystem development. Better and worse rankings of each member with respect to the EU28 average values were calculated. Thus, for example, countries such as Sweden (Se) or the United Kingdom (UK) with performances greater than the European average in all indicators have been classified with the category "high" DE for being positive in the two indices at the same time (CEI and DESI) versus the EU28 average. At the "middle" level of the DE, countries with only one indicator (DESI or CEI) greater than the average were grouped. The "low" DE level was of countries with indicators that at the same time were less than EU28 average rate.

As a result, according to Table 3.2, the following three categories of the DE were established:

- High DE: This ecosystem was formed by the countries with DESI and CEI indices greater than the EU28 average. Here, most of the countries of central and northern Europe are grouped.
- Medium DE: In this case, a group of countries was formed by Latvia, France, the Czech Republic, Spain and Portugal. The case of Spain (Es) in particular stands out for having better performance in the digitalization index of DESI compared to the European Union average, while its CEI and GVA indices are less than the average. Opening the focus on its CEI index, all of the indices that comprise it (Competitiveness - GCI; Employee engagement – EENG; and Innovation - GII) are negative, compared to the EU28 (2015 and 2017).
- Low DE: This category included those countries with DESI and CEI indices significantly less than those of the EU28. Nevertheless, it was observed that some of these countries shown good performance on their GVA. This outcome could be explained by these countries being developing economies and the value of their GVA being strongly dependent on other variables not analysed in this study. In any case, it is significant to see that these countries have recently joined the European Union, and they have still high volatility in their magnitudes. However, it is surprising to see Italy or Greece in this category.

With this new classification and in order to determine the probability that the GVA sign performance is associated with the probability of having a positive or negative DE (DESI or CEI) sign performance, the Bayes Probability Theorem methodology was used in Table 3.3 to confirm or refuse the hypothesis with non-parametric index variables. The results were the following:

Table 3.3 GVA and Digital Ecosystem Sign Conditional Probabilities

Hypothesis	Knowing B_j	A_j	$P(A_j/B_j) = \frac{P(A_j \cap B_j)}{P(B_j)} =$
H_1	$DESI^+$	GVA^+	0.615
		GVA^-	0.384
	$DESI^+ and\ CEI^+$	GVA^+	0.769
		GVA^-	0.230
	$DESI^+ and\ CEI^-$	GVA^+	0
		GVA^-	1
H_2	$DESI^-$	GVA^+	0.384
		GVA^-	0.615
	$DESI^- and\ CEI^+$	GVA^+	0.333
		GVA^-	0.667
	$DESI^- and\ CEI^-$	GVA^+	0.300
		GVA^-	0.700

Source: The author

According to Table 3.3:

Positive country value of GVA^+ with respect to the EU28 average has a greater probability of coming from its positive digital ecosystem indices $DESI^+\ and\ CEI^+ = 0.769$ than from the $DESI^+ = 0.615$ index in isolated mode, confirming H_1.

In contrast, negative country value of GVA^- with respect to the EU28 average has a greater probability of coming from its negative digital ecosystem indices $DESI^-\ and\ CEI^- = 0.700$ than from the $DESI^- = 0.615$ index in isolated mode, confirming H_2.

Therefore, positive GVA^+ has a poor probability of being obtained with any partial or total negative combination of the DESI and CEI indices. At the same time, negative GVA^- has a high probability of being obtained with any partial or total negative combination of the DESI and CEI digital ecosystem indices, confirming H_1 *and* $H_{2.}$

3.6. Conclusions and Limitations

First, the digital momentum concept has been developed in order to show in what way and at what speed each country is participating in the digital race. In this sense, countries such as Spain fit the “Outstanding” digital momentum presenting a DESI index greater than the EU28 average. At the same time, it has good speed and good digital trajectory growth (DESI Scaled Momentum). According to these two variables, value of the DESI index and speed of the digital trajectory, digital momentum of each country has been recorded allowing for the identification of the situation in which each EU28 countries are placed.

If it wanted to know where the digital competition race is, this magnitude would be very useful. However, knowing digital countries’ performances would not be sufficient because this information does not provide data about the potential imbalances that can occur in parallel. It could ask whether this digital momentum strategy prioritizes the digital installation stage or, in contrast, whether it follows the path of deployment (Van Ark, 2016). The fact is that taking one or other direction will prove to be a determining factor. Moreover, taking the wrong path can undermine a country’s future growth in terms of its GVA performance, creating a short-term illusion. For this reason, to understand what the real digital stage is and what digital form that each country takes will be critical to having a permanent scanning vision.

Second, using the concept of a DE and considering that the digital impact does not occur in isolation, digitalization plans require something else based on a country’s fundamentals, going beyond technological features. In this way, to include DE factors, such as competitiveness, innovation and employee engagement proxy and aggregate indices such as CEI have been used. Subsequently, they have been crossed with the DESI to determine potential imbalances between them by DEE. The objective has been to note whether a better or worse GVA performance indicates better or worse performance of an ecosystem index, excluding causation arguments. The model has confirmed the two hypotheses, verifying that the majority of countries with the best performance in GVA sign values also have a better CEI and DESI indices than the EU28 average. In other words, if countries drive innovation, competitiveness and employee engagement and add the digital factor to increase all of them, the effects on the GVA will have a high probability of being favourable, achieving consistent DE development.

Nevertheless, the countries with greater imbalances between their DESI value and CEI sign indices have lower values in GVA, presenting the case of positive values of DESI and negative CEI values translating into a negative value in GVA (Spanish case). Therefore, and according to what has been shown, countries' classification into three types of stages based on their DE (high, medium and low) has been presented.

Thus, digital momentum or a digital race would be short-sighted. Considering, for example, the case of Spain, its digital trajectory in recent years has led it to an outstanding position with a DESI value (53.5 out of 100) greater than the EU28 average (52.4) with enviable digital speed. However, analysing GVA trends over the last six years with respect to the EU 28 average, its performance has been substantially lower (-2pp B/W) for the period of 2010-2016 than the European reference point.

It is true that such as macroeconomic magnitude as this GVA value is the result of multiple factors that go beyond the present study. Despite this fact, good results in the DESI or digital momentum are not sufficient. Spain's practical digital mark is revealed in its indices such GII (-1.05), GCI (-1.55) and EENG (-9.41). All of these values are far from the EU28 averages, showing that the Digital Transformation model deployed in Spain is focused on the digitization manner, poor digital transformation and low DE. Therefore, on the one hand its poor DE with unfavourable variables could not increase GVA, and on the other hand, positive digital variables without the rest could not increase GVA being this country in digital installation stage (Van Ark, 2016). This way of digitization focuses on processes, cost controls, and the increasing network of people and things, but it forgets the importance of innovation, lacks more competitive environments and misunderstands the importance of employees' engagement in companies or institutions. In other words, according to Ross digital transformation definition (Ross, 2017) it's as a value proposal focused on the people (customer or citizen) that goes beyond exclusively technological factors and that includes ingredients such as innovation, competitiveness or employee engagement, among others, generating a DE, this country does not have a high DE despite its winning the digital race. Therefore, this country has a high DESI with good digital speed but with low levels in other fundamental economic pillars.

Third, the starting hypothesis has been confirmed and it concludes that, at a better level than that of DESI and CEI indicators in alliances, there corresponds a greater probability of a positive GVA.

Fourth, it will be very risky to focus exclusively on improving a single index. Regarding this fact, the model includes countries such as Romania (Ro), Poland (Po) and Bulgaria (Bg), among others. These countries present good indicators in their GVA values despite also having strong imbalances between their DESI and CEI indices. An analysis of these exceptions falls outside the scope of this study and could be due to growth models, corresponding to developing countries recently incorporated into the EU28 and the volatility of which in the delivery of their magnitudes is very high. Conversely, the model presents countries with good equilibria between their indices and, in a high digital ecosystem stage, scarcely lower values of the growth of their GVA (Holland, Finland and Denmark). This finding might be due to the variables that impact GVA performance value being multiple, sometimes even singular, for each country. This study in no case aims to find correlations or causalities among the set of variables.

Overall, countries with high DE have a greater probability of attaining better GVA values rather than medium or low values. In other words, this stage difference could determine the future possibilities of jumping from the "Internet of information" to the "Internet of value".

It has been presented that country or business DT is important, but it would seem that it is not sufficient to grow. It has been necessary to emphasize that, rather, it is about building a strong DE, maintaining a proportion of the high impact factors explained above to stimulate countries' balanced growth doing that DE acts as a knowledge connector between agents advancing value. Thus, public and private policies should be fundamentally ensuring actions to boost the variables of digitalization, innovation, competitiveness and employees engagement in a joint manner, thus avoiding isolated technology pushing out a high DE.

As a final conclusion, country digitalization and its implications require a peripheral vision that considers the ecosystem that the digital nerve affects. Advances in the digital index exclusively, such as digitizing or technology driver exclusively, do not guarantee country growth when important factors, such as innovation, competitiveness or employee engagement, among many others, are stagnant. Digital transformation requires a solid and growing foundation and a strong and consistent DE considering tech, social and management aspect to exploit its full potential by advancing and connecting endpoints. Thus, technology is very necessary but is not sufficient.

As a limitation, this study has not analysed causality factors and their relationships, leaving them for future analysis. In this study, digitalization was investigated in its aspects related to a specific set of official indicators (DESI, GCI, GII) or its own elaboration (EENG), while other factors, indices or data in the digital and country economic environment were not considered. Third, there is no mention of the business processes or companies'/industries' models or other very important variables, such as education system, poverty levels, resources capabilities, trade opening rate and many more. In addition, the model used has not included the level of sectoral specialization of each country, its "ad hoc" competitive advantages or other factors, such as monetary, fiscal, employment or inflation policy, although it has avoided, as far as possible, the fiscal policy effects operating with the GVA instead of GDP (Gross Domestic Product). Another notable limitation is that the index has been weighted at the same level for the proxy of the CEI aggregate index because analysis has not pretended to find the causal relationships or any type of correlations between the variables used.

Finally, the study has not included other countries outside the EU28, which would give it additional value by containing more information and offering a broader spectrum of contrast for the confirmation of the starting hypotheses. Potential areas of study could be how to include other variables such as the platforms, the monetization, human behaviour or the programmable economy in digital ecosystems or applying quantitative methods or other methodologies or models. Particular DE applications could be developed such as sustainability in cities or even the possibility of researching other indices different than DESI and CEI and even carrying out this exercise with other countries outside the European Union or to investigate the difference between developed and developing countries digital transformation.

Chapter 4

Digital Assets Horizon in Smart Cities: Urban Congestion Management by IoT, Blockchain / DLT, and Human Reinforcement

Digital Assets Horizon in Smart Cities: Urban Congestion Management by IoT, Blockchain / DLT and Human Reinforcement (1)

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Abstract

Cities are the future of humanity and for the coming majority, their next great home. This rapid urbanization of the planet presents great challenges and, at the same time, great opportunities. On the one hand, the concentration of people in urban spaces provides numerous economies of scale but, on the other hand, also implies the potential generation of negative externalities that it should be managed by a "smarter city" to find a balance. Mobility in cities, the fact that moving in a vehicle (fuel, electric, shared, autonomous), public transport or other means is becoming a common, difficult and complex congestion problem for cities, has negative economic consequences. This enormous pressure for efficiency and the search for solutions are making significant inroads into the incorporation of ICT in Smart Cities and subsequent large-scale digitalization to resolve this issue and other setbacks. This deployment needs to be conducted with a broad perspective incorporating economics and human concepts such as digital assets or citizen incentives in city strategies because in cities, people and resources are key players.

Using a forgotten effects methodology, the present exploratory work shows a new model of city congestion management deploying the possibilities offered by some disruptive technologies such as the Internet of Things (IoT), blockchain / distributed ledger technology (DLT) and token economy, combined with a human capital aspect such as a reinforcement theory. The potential possibilities that these concepts have in future

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mobility and other fields are large in terms of moving towards a more sustainable, decentralized and intelligent management enabling an authentic digital jump.

Keywords: Internet of Things, Distributed ledger technology, Blockchain, Smart cities, Congestion pricing, Motivation

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4.1. Introduction

Currently, 55% of the world's population lives in urban areas. It is expected that in 2045 there will be 6 billion people living in cities, which will increase the current figure 1.5 times. Far from stagnating and looking beyond, it is expected that by 2050 the number of urbanites will reach 68% of the total world population (The World Bank, 2018). This rapid urbanization that it is facing presents great challenges and great opportunities. The concentration of people in urban spaces provides numerous economies of scale, but at the same time, it implies externalities that should be managed including city congestion. The concept of externality is not specific to environmental issues and it is used to define situations where the activities of one (or more than one) economic agent(s) have consequences on the economic well-being of other agents, without any kind of exchange or transaction occurring between them (Papandreou, 1994).

This enormous pressure for urban space efficiency is opening the way to the incorporation of information and communication technology (ICT) in Smart Cities (SC), the Internet of Things (IoT) is especially relevant as a source of cities' efficiency management, and a balance needs to be considered between the technological aspects and human capital (Perera *et al.*, 2014; Gil-García *et al.*, 2016). It is not only about maximizing city digitization. It should be a step beyond the pure connectivity of the SC 1.0 models and move towards optimization in decision making formulas that offer a quality of life for citizens and visitors based on a greater collaborative and consultative effort constructed on three objectives: to achieve a connected city, an intelligent economy and an innovative government where all the actors work together. Despite the fact that technology will play an important role in the future, there are other "soft" factors such as citizen participation, collaboration and the reward of the intangible to be take into account in cities because one of the fundamental objectives of technology is to make better use of public resources, increase the quality of services offered to its citizens and, at the same time, improve the quality of life by stimulating the innovation process in the urban ecosystem (Cooray *et al*., 2017; Zanella *et al*., 2014; Giudice *et al*., 2011). Today's cities have become different systems characterized by abundant and continuous interconnections of their citizens, business, transportation, networks and communications.

The adjective "smart" added to the word cities can be traced back to the idea of the "smart growth movement" of the late 1990s whose promoters advocated new policies for urban planning. Subsequently, this concept was adopted by a large number of technology companies for the application of ICT complex systems (Harrison *et al*., 2011). Current reality leads to the fact that there is no common definition regarding the SC concept; however, there would be some consensus that these are characterized by a sharp use of ICT, although the deployment of these technologies does not necessarily guarantee a better city.

From a technological outlook, the literature review notes two major ICT roles in cities: on the one hand, there would be a technological role to improve productivity through the automation of routines and processes favouring better decision making. On the other hand, a body of studies would appear to place the focus on the human capital role, improving liveability by supporting and motivating the development of talent, participation and education. Thereby, there are two different views, one focused on optimization with the best urban intelligence management resources or "top-down" and the other focused on a "bottom-up" position where the city provides access to data and citizens make their own decisions. In this way and depending on the application and importance of ICT, two domains emerge: "hard" (with a greater preponderance of the application of new technologies in the fields of energy, resource management, environment, transport and mobility, residential, health, and safety) and "soft", where the ICT role is more limited - education, social inclusion, governance, economy, and innovation (Neirotti *et al*., 2013). Thus, there is no doubt that the deployment of ICT in cities is having a large impact on how a city is planned and organized and, more importantly, how the networks are established between the subjects and objects, from the social aspects to the economic ones - mobility, connectivity, consumers, commerce, taxes, resources, management, and collaboration (Batty *et al*., 2012).

Going beyond that, for the most advanced cities, the SC 1.0 phase (connectivity ecosystems) is evolving towards the SC 2.0 phase, seeking to move beyond infrastructure interconnection towards an optimization in the decision-making process through all actors' data management (governments, businesses and residents), offering a higher quality of life for citizens and visitors, greater economic competitiveness and an increase in sustainability and environmental awareness (Ottawa, 2017; Eggers *et al*., 2018). This evolution should be based on new forms of collective intelligence (Malone *et al*., 2011) where governments push the creation of inclusive and open environments and platforms. This evolution requires a greater intelligence function to improve the coordination of different elements ensuring private, safety and transparent bidirectionality of information between administrations and citizens. Debate between what type of SC governance should have (centralized or decentralized) that allows efficiency, security, privacy and transparency is actually open.

The objectives of this paper are first rethink one of the most SC pressing problems, that is, mobility and, in particular, traffic congestion management and their externalities exhibiting Smart Congestion Management Model (SCMM); second, open a new citizen's role in cities administration by considering their decisions making process with more participation through truly end-to-end digitalization system that combine ICT and human capital when sustainability like urban congestion is managed as a value that can be captured and exchanged in a trusted environment. It is argued that any proposed solution in the SC congestion issue should be carried out under a holistic approach that integrates the idea of the different typologies of SC functions - smart people, smart economy, smart mobility, smart environment, smart living and smart governance (Batty *et al*., 2012). Therefore, delving into formulas that increase such integration, it is postulated that ICT advantages, in particular offered by IoT and blockchain / DLT and token economy, in addition with the promotion of the citizen reinforcement, has a superior solution in order contribute to solve the urban congestion issue in cities.

This paper is organized as follows: in Section 2, the theoretical background is described. In Section 3, the methodology is presented, followed in Section 4 by the results. Finally, Section 5 summarizes the most important conclusions of this paper.

4.2. Theoretical Background

4.2.1. Smart Cities Mobility

Cities move. Citizens and goods travel around cities by some type of vehicles from end to end in a frenetic nonstop motion through the combination of driving private or commercial vehicles, shared vehicles and public transport. Behind this increasing mobility, four new trends are observed that will mark the future, changing the way mobility is understood -electrification, autonomy, connectivity and sharing- (Hannon *et al.*, 2016).

Although the mobility concept is evolving, the underlying architecture needs to change. Consider some negative inefficiencies: in Boston, more than 40% of the vehicles during rush hour have only one occupant or vehicles are being used whose weight is 20 times that of the occupant; there is a misunderstanding with electric vehicles and the concept "zero emissions", which is not the same as "zero carbon emissions"; or in cities such as London, 24% of the urban area is allocated to roads, and this percentage reaches 40% in some cities in the United States (Sumantran *et al.*, 2018). City mobility has substantial problems in terms of difficult management such as management associated with pollution, climate change, urban congestion or energy consumption as cities consume up to 2/3 of the world's energy and account for more than 70% of greenhouse gas emissions (The World Bank, 2018).

Specifically, in terms of mobility aspects, understanding how the elements combine and interact in a city is truly complex and depends on the situation of each city. In this way, there are ten essential factors grouped into three blocks to understand city mobility in a clear and efficient way (Bouton *et al.*, 2015): 1- depending on medium typology (private vehicle, walking or cycling, public transport, or new transport models); 2- according to the underlying system form (policies and regulations, urban design and land use, preferences and behaviours of consumers); and 3- the type of facilitators (financial, technological, or business models). Combinations of these factors will determine the basic mobility characteristics of each city as a unique case due to the concrete combination of factors.

The Horizon 2020 Program of the European Union includes objectives related to urban mobility and preferences within the Specific Program of SC4 "Intelligent, ecological and integrated transport" (European Commission, 2017). This section is structured into four main types of activities: a) efficient transportation in terms of resources that respect the environment; b) better mobility, less congestion, and more security; c) global leadership for the European transport industry; and d) socio-economic and behavioural research and prospective activities for the formulation of policies to face the challenges posed by transport.

It is clear that sustainable mobility is a very important challenge, but a more ecological technology is not the solution. Having a higher vehicle fuel efficiency, the incorporation of electric vehicles (EV), an increase in the sharing economy or the appearance of autonomous vehicles (AV) adapted to consumer demand can become a potential for an increase in vehicle traffic rather than a decrease (Hahn, 2011). Consider, for example, the evolution of commercial vehicles (CV) that handle home deliveries generated from commerce online and whose demand in cities is increasing significantly. It is expected that by 2025, approximately a quarter of American cities' population will use rapid delivery services on the same day (Bouton *et al.*, 2017).

One of the most devastating city mobility effects is the congestion that results from it, considering this effect an aspect of inefficiency. It is estimated that the congestion impact on GDP (gross domestic product) in most cities is 2 to 4% in terms of waste of time or energy and the cost increase of doing business (Bouton *et al.*, 2015). Thus, it is estimated that in the United States alone, congestion costs in cities will increase by 20% from 160 b $ in 2014 to 192 b $ in 2020 (Bouton *et al.*, 2017).

The problems behind urban congestion are multiple. Focusing on productivity, the amount of time wasted in traffic is alarming and increasing. For example, Mexico City led the congestion index at 66% for 2016 (Tomtom, 2016) -extra time needed for a vehicle to make the same journey on a congested road compared to a fluid traffic situation-. Regarding this perspective, a worldwide snapshot by countries in 2017 provided by an INRIX consultant (INRIX, 2017) say that Thailand, Indonesia, Colombia, Venezuela, Russia, the U.S., Brazil, South Africa, Turkey, and the U.K., in this order, are the "top 10" congestion countries ranked. The effects of this problem are dramatic because the costs incurred by these countries have a great impact on productivity in terms of GDP. Thus, as the Cookson CEO of INRIX (INRIX, 2017) advises, "*Congestion costs the U.S. hundreds of billions of dollars, and threatens future economic growth and lowers our quality of life…*"

With this perspective, there are some solutions that are being put in place to face this great challenge. A literature review offers several proposals. First, it is found citizen journey customization on a connected transport network by multimodal solutions (users can choose the best travel option at any time through the incorporation of ICTs and intelligent driving). Second, there has been a focus on accessibility and increasing the proximity concept (bringing the things we need more where we need them), eliminating the need to move through better urban planning and local production or by increasing technology penetration - teleservices (Zielinski, 2012). Third, some cities are deploying driving restrictions or limitation in certain types of vehicles - Hamburg prohibits the circulation of the oldest and most polluting diesel vehicles in certain areas and streets- (Europapress, 2018). Fourth, restrictive measures are being implemented prohibiting the driving of cars with odd or even number on alternate days is adopting in Madrid, Mexico, Beijing, Bogota, Caracas, and Santiago de Chile, and finally, there are toll initiatives (congestion pricing) where the vehicles that want to access city centres during in rush hour must pay for the privilege (Singapore, London, Stockholm, Milan, and Gothenburg). The final measure is supported by a recent study about a congestion pricing viability tax to avoid traffic jams and pollution in large cities (Fageda *et al*., 2018).

It is time to explore new opportunities if cities want to change mobility habits. Mobility outside the car should be more attractive for citizens. This requires attractive public transport accessible to all users (elderly, disabled, and parents with young children) where the mobility experience is positive with the existence of attractive transport nodes and enabling green or blue corridors to increase the pleasure of going on foot or by bicycle (Hahn, 2011). Cities and their leaders are introducing some measures to integrate mobility alternatives, for example, multimodality promotion with harmonized tariffs systems, new payment systems and the integration of flexible schedules, all unified through Internet applications close to the users.

These particular measures, in some way, are contributing greatly to better mobility and a reduction in urban congestion, but considering citizen habits as a cornerstone, all of these actions are not enough. In this way, looking for a better resources combination, mobility and congestion solution could be accelerated through a better arrangement of digital technology, in particular those offered by the IoT, blockchain / DLT and token economy, combined with citizen reinforcement theory, encouraging habit changes.

4.2.2. Digitalization by Internet of Things, Blockchain / DLT

Enormous pressure towards SC efficient management is accelerating the use of ICT, discovering proper solutions. Among many other technologies behind the ICT concept, currently there are two major phenomena, the IoT (Internet of Things) and the blockchain / DLT (distributed technology ledger), revolutionizing the way that cities are understood.

IoT earns more attention for its applicability in SC from different perspectives including social, economic, and technological ones. Cities can manage their resources more efficiently from these points of view, offering new value solutions that make the decision processes swifter (Perera *et al*., 2014). IoT allows people and things to connect at anytime, anywhere, with anything and anyone that ideally uses any route / network and any service (Vermesan *et al*., 2009). For example, the Telefónica Company (TelefonicaIoT, 2018) notes, "*The hours lost in the long traffic jams in cities will be able to be invested in what truly matters thanks to the Internet of Things."*

Blockchain / DLT allows for the appearance of the so-called "crypto-cities", transforming how cities coordinate and organize. A crypto-city is one that strives to open and decentralize city data using crypto-economy tools and technology (Potts *et al*., 2017). Thus, although the blockchain technology is a remarkably transparent and decentralized way of registering lists and transactions, this will not be the solution to all city problems. It will have a large impact in many areas. In particular, its deployment in the sphere of the public sector will affect a large number of activities. According to the European Parliament (Boucher *et al*., 2017), blockchain technologies can provide new tools to reduce fraud, avoid errors, cut operating costs, boost productivity, improve compliance and improve accounting.

From another angle, IoT and the blockchain / DLT deployment can contribute to enlarging an intelligent economic systems such as programmable economy that allow cities to manage the production and consumption of goods and services in a different way. These technologies would form new and diverse scenarios of value exchange, both monetary and non-monetary (Gartner, 2015). Overwhelmingly, this disruption allows for taking a further step towards IoT monetization, and therefore, it will be possible to convert urban physical or intangible assets (such as urban space or traffic congestion) as a digital asset, opening the possibility to creating new business models of management and revolutionaries' citizens and city interactions in a transparent and decentralized way.

Thus, these technologies will help to improve how cities and citizens connect (IoT) and how they are coordinated and organized (blockchain / DLT). However, if it wants to change mobility habits, it would need to add the human behaviour factor. Tomorrow's cities (SC 2.0) are looking for positive citizens 'and visitors' experiences, and they need to consider how to motivate them.

In this sense, the theory of motivation investigates why people vary their level of motivation, as well as determine the reasons why people are motivated. The majority of motivation´s definitions do it by scholars have three common denominators. They are all essentially concerned with factors or events that energize, channel, and sustain human behaviour over time. In various ways, contemporary theories of motivation derive from efforts to explain with increasing precision how these three factors interrelate to determine human behaviour in organizations or cities (Steers *et al*., 2004).

4.2.3. Human Factor. Incentives and Motivation

City congestion cannot be solved by Adam Smith's invisible hand because it fails to find an efficient result for those who are not part of the transaction but suffer the costs and benefits of the externalities, that is, the group of citizens; hence, the appearance of the so-called Pigouvian rates (Mankiw, 2009). Therefore, it could make use of some factors beyond the technological and economic ones such as human reinforcement and motivation in order to stimulate and involve citizens in congestion resolution.

The theory distinguishes among diverse types of motivation in terms of the different underlying attitudes, reasons and objectives that give rise to the action. The clearest distinction is between intrinsic motivation - doing something because it is intrinsically interesting or pleasurable - and extrinsic motivation - doing something because one is externally forced to do it or because the action will lead to some type of reward or result (Ryan *et al*., 2000).

One of the ways to provide motivation is through the application of reinforcement theory, also known as learning theory (Skinner, 1953). This refers to the stimuli used to produce desired behaviours. B. F. Skinner argued that for motivation, it is not necessary to understand individual needs, as proposed by the theories of the content of motivation. Skinner proposed that the administrator needs to only understand the relationship between behaviours and their consequences to create conditions that encourage desirable behaviours and discourage undesirable ones. Behaviour is learned through its positive or negative consequences. Reinforcement theory is widely used in organizations as an instrument to increase or decrease employees' behaviour and as a key factor to motivate staff (Wei *et al*., 2014). This appreciation could be used in city management in order to motivate citizens and reinforce or dissuade their mobility habits.

Using incentive factors, citizens can increase their participation in city decision making, they can transform the city vision from "car-centric", anchored in the years 1920-30, to a “people-centric” vision based more on the idea of walking, riding, cycling or using public transport, which is greatly linked to tomorrow's cities ’appropriate future concepts (World Economic Forum, 2015). Therefore, positive and negative citizen reinforcements are fundamental points in the treatment of the congestion problem and it becomes central.

Based on the above, the following hypotheses are presented for the Smart Congestion Management Model (SCMM) :

H1- Negative incentives (congestion pricing, CP) applied to (private and commercial) unfriendly vehicles contributing to better mobility in cities.

H2- Positive incentives (uncongestion pricing, UP) applied in friendly vehicles contributing to better mobility in cities.

Friendly or unfriendly vehicles have been defined regarding the urban transport environmental impact in developed countries according to their efficiency in terms of respecting the environment while minimizing the impact on climate greenhouse gases (CHG), (World Health Organization, 2011): 1-Unfriendly: 61-170 max Co2-eq emissions / passenger by travel (-gasoline, diesel, electric- cars, motorbike, vans, trucks, coach). 2-Friendly: 25-60 max Co2-eq emissions / passenger by travel (bicycles, scooters, public transport-train, metro, bus).

4.2.4. Efficiency, Coordination and Transparency

However, could all of these incentives be managed by current institutional systems ensuring, at the same time, efficiency and transparency process management? The backbone that will help with this characteristic will be the combination of IoT, blockchain / DLT technologies plus smart contracts and token economy elements because these digitals concepts will be crucial in city governance and sustainability (Dao, 2018), as will be seen below.

Blockchain technology is found in the paper "Bitcoin: A Peer-to-Peer Electronic Cash System" by Satoshi Nakamoto (Nakamoto, 2008) and refers to a particular way of organizing and storing information and transactions between peers (peer to peer). Blockchain is one type of a distributed ledger. Distributed ledgers use independent computers (referred to as nodes) to record, share and synchronize transactions in their respective electronic ledgers instead of keeping data centralized as in a traditional ledger (The World Bank, 2018). It can define this blockchain technology as a list of irrevocable transaction records, cryptographically signed, shared by all participants in a network, in a peer-to-peer manner (Gartner, 2018).

This technology enables the second generation of the Internet, from “Internet of information” to “Internet of value” radically changing the operational of the economy and of institutions (Tapscott, 2017). Analysing this technology scope within the digitalization sphere using Gartner's DD (Digital Disruption) scale, currently this technology is in the DD1 stage or initial phase of disruption, and it will reach DD3 stage or transformation stage in 2023 estimating that the value generated by this in the economy world will be 176 b $ in 2025 (Kandaswamy *et al*., 2018).

Blockchain / DLT technology drastically reduces the cost of trust and allows for imagining new business models and opens the possibility to deploying new forms of collaboration at the same time. As a source of trust, it can expand organizations and institutions DT degree where they can share processes among all actors, which is possible because this technology makes the information contained within immutable, safe, shared and consensual (Harvard Business Review, 2017). Additionally, this registry allows for expanding the smart contracts concept or intelligent contracts, a concept attributed to Nick Szabo (Szabo, 1996). He observed that contracts between parties are one of economic capitalism’s pillars, and they are similar to the computational programs, as they are representations in the form of code of the same processes while allowing to certify them. In other words, organizations and institutions can agree in such contracts as to how they want their business or public services to be carried out in a consistent and automated manner, keeping participant interactions’ records in a transparent manner at all times. This technology allows for a better decision-making process either between people or between machines without human intervention.

It is usually assumed that a SC tends to increase its bureaucracy. One of the most important characteristics of this technology is that it allows for reducing, in a very consistent manner, the so-called “transaction costs” defined in Coase's work “The Nature of the Firm" (Coase, 1937), where the choice between the organization or the market is essentially an exercise in minimizing costs. These costs would include the cost of organization, negotiation, monitoring, information and coordination (Potts *et al*., 2017), digital technologies clearly can reduce many of these costs and blockchain / DLT technology tends to reduce decisions and many coordination functions could be replace by the smart contracts software.

Therefore, an approach of city management and more specifically citizen´s mobility and urban congestion treatment and control by transaction cost theory, can open new institutional possibilities in order to reduce transaction costs, control, and monitoring expenses and give them the possibility to achieve more efficient data coordination.

Thus, blockchain / DLT technology allows for a strong move towards connected mobility by using smart contracts and digital wallets in all types of vehicles. This innovation means carrying out all transfers through the blockchain / DLT, which recognizes its activation under certain conditions (Sandner *et al*., 2017) that institutions can define. In this way, unfriendly vehicles can make certain token transfers automatically to pay congestion charges (congestion pricing) for accessing a specific city area. In contrast, friendly vehicles (and their owners) can obtain positive incentives (Uncongestion Pricing) if they access the same area in a more sustainable manner, in the form of this token and using them such that with public transport discounts or paying local tax or commerce coupons, they can exchange tokens by fiat money, all with minimal human interaction.

Thus, IoT allows people and things to be connected anytime, anywhere, with anything and anyone, ideally using any route / network (Vermesan *et al*., 2009). This technology can be used in order to know which vehicles or individuals access certain city areas with high urban congestion while maintaining their privacy. In addition, token economy and blockchain activate the possibility to deploy the digital asset concept (digital asset market in representation of the physical assets), preventing duplication through the generation of smart contracts or protocols that facilitate, verify and execute the terms of the city contract, all thanks to the fact that tokens or units of value can be employed to make the payment (Kandaswamy *et al*., 2018).

Thus, through these technologies, it is possible to create a new city congestion scenario to manage and negotiate access to any vehicle for specific areas, giving citizens positive or negative incentives and dissuading unfriendly vehicles from use while encouraging friendly ones such as public transport or bicycles opening the door to be able to exchange these incentives between the agents.

Blockchain / DLT and IoT applied to the institutional administration become and excellence technologies in the governance and decentralization way. Their impact on productivity and efficiency can be extremely beneficial (Davidson *et al*., 2018). In particular, blockchain / DLT can be a good tool to reduce fraud, avoid errors, reduce costs, promote productivity and strengthen compliance in public services. Future applications can provide some benefits such as tax payment system, identification tool, benefits distribution platform, issuance of local digital currencies, or property registers (UK Government Chief Scientific Adviser, 2016).

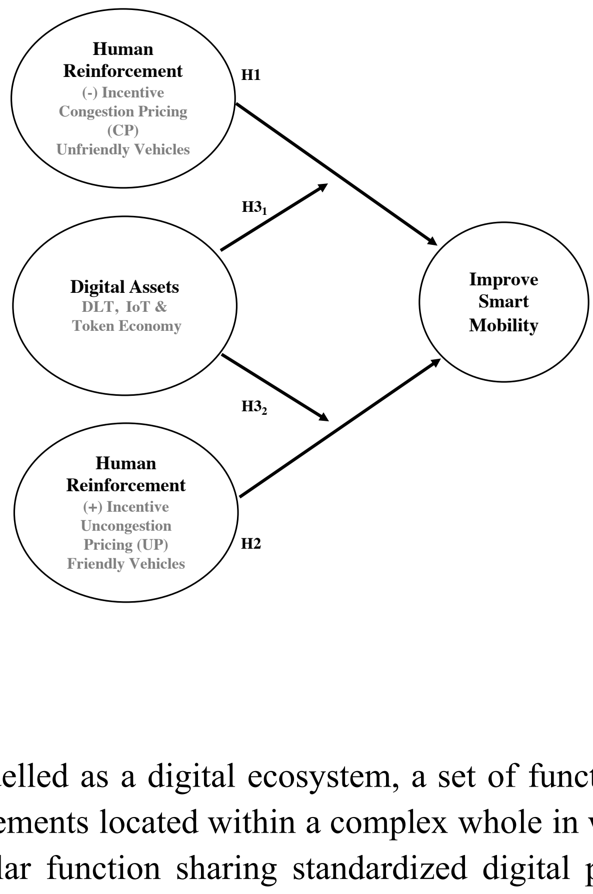
This type of technology has been applied in different automotive use cases such as vehicle identification, payment of tolls and EV charging (allowing automatic, transparent and frictionless payment), and it is offering some advantages such as decreasing complexity, no transaction fee and many implications of the machine-to-machine economy, modelling new business models by, for instance, IOTA utility token applications and the tangle possibilities in SC such as Taipei or Pangyo among others (Pauseback, 2018).

Thus, considering the SC dimensions under the European prism mapping SC in the EU (smart economy, smart people, smart mobility, smart environment, smart governance, and smart living), which considers that any improvement included in one or more of these dimensions is a sufficient reason to consider a city as intelligent (European Parliament, 2014), the following hypothesis is presented:

$H3_{(1,2)}$ - Negative incentives (congestion pricing, CP) applied in (private or commercial) unfriendly vehicles combined with positive incentives (uncongestion pricing) applied in friendly vehicles by token economy (congestion pricing digital asset) and anchored in the IoT and DLT technologies contribute to be better smart mobility (reduce city congestion, improve institutional efficiency and recover city productivity) and better SC, greater than H1 or H2.

With H1, H2 and $H3_{1,2}$, the SCMM is described in Figure 4.1:

Figure 4.1 Smart Congestion Management Model (SCMM)



Source: The author

SCMM is modelled as a digital ecosystem, a set of functional niches and roles, a set of elements located within a complex whole in which each niche fulfils a particular function sharing standardized digital platforms (Rynn, 2007; Gartner, 2017).

4.3. Methodology

4.3.1. Incidents Analysis by Forgotten Effects

With the idea of determining the model's validity and calculating its overall effect, considering the direct and indirect incidents of each of the selected causes, the forgotten effects theory will be used (Kaufmann *et al.*,1988; Gil-Lafuente, 2008).

First, the causes "c" and the effects "e" of the SCMM are defined in Table 4.1:

Table 4.1 Causes and Effects in Smart Congestion Management Model (SCMM)

Causes	Effects
c_1: (-) Incentives, Congestion pricing (CP), Unfriendly vehicles.	e_1: Reduce traffic index (congestion level). e_2: Improve productivity (reduce waste of time). e_3: Improve environment (green areas and reduce noise/ Co2 pollution).
c_2: (+) Incentives, Uncongestion pricing, (UP) Friendly vehicles.	e_4: Improve health (personal stress, related diseases, accidents). e_5: Increase public transport and friendly vehicle use (bicycle, electric skates).
c_3: (- and +) Incentives (CP&UP), Unfriendly and friendly vehicles by Blockchain / DLT & IoT & token economy.	e_6: Improve local financial resources. e_7: Increase institutional governance efficiency (reduce transaction cost and monitoring). e_8: Increase connectivity, network (digitalization). e_9: Increase citizen participation (P2P, Apps). e_{10}: Built the backbone to deploy others digital assets (reward citizen behaviour).
Source: The author	

To determine the incidences of the causes among themselves, the incidents between the causes and the effects, and the effect incidences between them, a survey was developed with experts to obtain an assessment with a scale of 0.0 to 1.0 (decimal scale) in order to know these incidents. In this way, the value of the incidence between the variables is assigned (1.0 value means significant and 0.0 value means not significant); it has been considered that the incidence of a variable on itself is total, so the assigned value is 1.0. In this way, three necessary matrixes must be calculated in order to obtain forgotten effects:

With C = (c_1. c_2,..., c_n) being a set of causes and E = (e_1. e_2,..., e_n) being a set of effects, the incidences of the elements of C on the elements of E, (c_i,

$e_j) = \mu_{ij}$ can be valued in the interval $[0, 1]$, with the assigned value being greater, the more intense the incidence is. Therefore:

$$\mu_{ij} \in [0,1]; c = 1,2,\dots,n; e = 1,2,\dots,m$$

Then, the following matrixes are built in Table 4.2:

Table 4.2 Causes and Effects Matrix

1- Between causes matrix	$[\tilde{C}] = \begin{matrix} & c_1 & c_2 & \cdots & c_m \\ c_1 & \propto_{11} & \propto_{12} & \cdots & \propto_{1m} \\ c_2 & \propto_{21} & \propto_{22} & \cdots & \propto_{2m} \\ \cdots & \cdots & \cdots & \cdots & \cdots \\ c_n & \propto_{n1} & \propto_{n2} & \cdots & \propto_{nm} \end{matrix}$
2- Between effects matrix	$[\tilde{E}] = \begin{matrix} & e_1 & e_2 & \cdots & e_m \\ e_1 & \beta_{11} & \beta_{12} & \cdots & \beta_{1m} \\ e_2 & \beta_{21} & \beta_{22} & \cdots & \beta_{2m} \\ \cdots & \cdots & \cdots & \cdots & \cdots \\ e_n & \beta_{n1} & \beta_{n2} & \cdots & \beta_{nm} \end{matrix}$
3- Between causes and effects matrix	$[\tilde{M}] = \begin{matrix} & e_1 & e_2 & \cdots & e_m \\ c_1 & \mu_{11} & \mu_{12} & \cdots & \mu_{1m} \\ c_2 & \mu_{21} & \mu_{22} & \cdots & \mu_{2m} \\ \cdots & \cdots & \cdots & \cdots & \cdots \\ c_n & \mu_{n1} & \mu_{n2} & \cdots & \mu_{nm} \end{matrix}$
4- Global matrix	$[\tilde{M}^*] = [\tilde{C}]^\circ[\tilde{M}]^\circ[\tilde{E}] = \begin{matrix} & e_1 & e_2 & \cdots & e_m \\ c_1 & \omega_{11} & \omega_{12} & \cdots & \omega_{1m} \\ c_2 & \omega_{21} & \omega_{22} & \cdots & \omega_{2m} \\ \cdots & \cdots & \cdots & \cdots & \cdots \\ c_n & \omega_{n1} & \omega_{n2} & \cdots & \omega_{nm} \end{matrix}$
Source: The author	

$$\forall(c_i, c_k) \in [\tilde{C}]: \propto_{ik} \in [0,1]; i = k: \propto_{ii} = 1$$
$$\forall(e_i, e_l) \in [\tilde{E}]: \beta_{il} \in [0,1]; j = l: \beta_{jj} = 1$$

The matrix $[\tilde{M}^*]$ will be the result of first making a convolution (°) between the matrix of causes and the matrix that includes the direct incidents of causes and effects:

1st Convolution maxmin:
$$\upsilon(c_n, e_m) = \vee (\alpha_{nn} \wedge \mu_{nm})$$

and, later, a second convolution between the resulting matrix $\left[[\tilde{C}]^{\circ}[\tilde{M}]\right]$ and the matrix that collects the incidents between the variables of the effects $[\tilde{E}]$.

2nd Convolution maxmin:

$$\omega(c_n, e_m) = \vee\,(\upsilon_{nn} \wedge \beta_{nm})$$

Finally, once the global incidents $[\tilde{M}^*]$ have been obtained, if it subtracts the direct incidents of the causes on the effects $[\tilde{M}]$, it can determine the indirect incidents of each one of the causes on the effects or forgotten effect matrix.

$$[\widetilde{M^*}] - [\tilde{M}] = \begin{array}{cccccc} & e_1 & e_2 & \dots & e_m \\ c_1 & \theta_{11} & \theta_{12} & \dots & \theta_{1\,m} \\ c_2 & \theta_{21} & \theta_{22} & \dots & \theta_{2\,m} \\ \dots & \dots & \dots & \dots & \dots \\ c_n & \theta_{n1} & \theta_{n2} & \dots & \theta_{nm} \end{array}$$

4.3.2. Sample

To carry out the investigation, the project has been divided into two phases: in the first phase, the model has been tested with two SC experts, later introducing the acquired learning, and proceed to phase two, extending the experts number to 10 in the fields of institutional, technology, blockchain, urban planning, public transport, private sector, automotive industry, and commerce as well as academic.

The first phase model has been tested, carrying out two personal interviews with SC experts in the public administration and private enterprise sectors. The interview methodology started by explaining the model, and next, experts completed some matrixes (causes / causes ($[\tilde{C}]$), causes / effects ($[\tilde{M}]$) and effects / effects ($[\tilde{E}]$). Then, the experts shared their impressions and noted the following:

1. The estimated time to complete the matrixes was approximately 1 hour.
2. There were some conditioning issues in the matrix c/e and e/e answers (first five columns), so it was proposed to change their order.

3. Two different approaches emerged in the way of determining the matrix according to whether the expert belongs to the public administration or the private sector.
4. The public administration expert mentioned the importance of the slow tech adoption curve in the institutional environment.
5. The private sector expert mentioned that in public administrations some projects have difficulties depending on how many departments were involved with (with more department, there are more problems) and most important, large projects should require a long-term vision, members' commitments and strong political stability.
6. The experts agreed that the token economy and the digital assets phenomena can be exported to other SC projects beyond congestion management application.

4.4. Results

The variables used in this analysis are the same as those used in Table 4.3 of the previous section. With the intention of knowing the total incidences of the different types of causes on the variables (effects) of the SCMM, the forgotten effects methodology described in the previous section will be used.

$$[\widetilde{M^*}] = [\tilde{C}]\circ[\tilde{M}]\circ[\tilde{E}]$$

The preliminary results obtained follow this structure: First, the direct incidents between causes and the effects in SCMM are determined in Table 4.3. The values have been obtained as a result of applying an arithmetic average from the different scores of the experts.

Table 4.3 Incidents between SCMM Causes and Effects $[\widetilde{M}]$

$[\tilde{M}]$	e_1	e_2	e_3	e_4	e_5	e_6	e_7	e_8	e_9	e_{10}
c_1	0.20	0.20	0.20	0.20	0.40	0.45	0.55	0.10	0.10	0.10
c_2	0.60	0.60	0.60	0.60	0.85	0.20	0.30	0.25	0.40	0.80
c_3	0.75	0.75	0.65	0.60	0.85	0.50	0.80	0.75	0.65	0.80

Source: The author

Second, the incidences between the effects of the SCMM are collected in Table 4.4. The values have been obtained as a result of applying an arithmetic average from the different scores of the experts.

Table 4.4 Incidents between SCMM Effects $[\tilde{E}]$

$[\tilde{E}]$	e_1	e_2	e_3	e_4	e_5	e_6	e_7	e_8	e_9	e_{10}
e_1	1.00	1.00	1.00	1.00	0.60	0.10	0.10	0.40	0.50	0.35
e_2	0.30	1.00	1.00	1.00	0.70	0.80	0.40	0.40	0.35	0.25
e_3	0.20	0.45	1.00	1.00	0.25	0.40	0.20	0.30	0.35	0.30
e_4	0.10	0.65	0.40	1.00	0.80	0.55	0.50	0.40	0.45	0.30
e_5	0.90	0.70	0.90	0.45	1.00	0.35	0.35	0.25	0.40	0.40
e_6	0.45	0.40	0.50	0.40	0.70	1.00	0.85	0.50	0.50	0.40
e_7	0.35	0.70	0.50	0.20	0.45	0.80	1.00	0.90	0.60	0.50
e_8	0.70	0.75	0.50	0.35	0.60	0.70	0.85	1.00	0.85	0.85
e_9	0.50	0.85	0.65	0.50	0.80	0.50	0.70	0.65	1.00	0.85
e_{10}	0.85	0.80	0.65	0.35	0.65	0.75	0.75	0.65	0.85	1.00

Source: The author

Third, the incidences of the different types of causes among themselves are determined in Table 4.5. The values have been obtained as a result of applying an arithmetic average from the different scores of the experts.

Table 4.5 Incidents between SCMM Causes $[\tilde{C}]$

$[\tilde{C}]$	c_1	c_2	c_3
c_1	1.00	0.35	0.85
c_2	0.55	1.00	0.90
c_3	0.75	0.85	1.00

Source: The author

Fourth, the global incidence is obtained, both direct and indirect, through the "maxmin" first convolution process.

$$[\widetilde{M^*}] = [\tilde{C}]\circ[\tilde{M}]\circ[\tilde{E}]$$

as shown in Table 4.6:

Table 4.6 Global Incidence - Total Cause/Effects on the SCMM $[\tilde{M}^*]$

$[\tilde{M}^*]$	e_1	e_2	e_3	e_4	e_5	e_6	e_7	e_8	e_9	e_{10}
c_1	0.85	0.85	0.75	0.85	0.85	0.80	0.80	0.80	0.80	0.80
c_2	0.85	0.85	0.75	0.85	0.85	0.80	0.80	0.80	0.80	0.80
c_3	0.85	0.85	0.75	0.85	0.85	0.80	0.80	0.80	0.80	0.80

Source: The author

Once the global incidents have been obtained, if it subtracts the direct incidences of the causes on the variables of the SCMM (which have been obtained in the first step), then it can know the indirect incidences of each of the causes on the variables of the SCMM by the second convolution process, as can be seen in Table 4.7:

Table 4.7 Forgotten Effects in SCMM $[\widetilde{M^*}] - [\widetilde{M}]$

$[\widetilde{M^*}] - [\widetilde{M}]$	e_1	e_2	e_3	e_4	e_5	e_6	e_7	e_8	e_9	e_{10}
c_1	0.65	0.65	0.55	0.65	0.45	0.35	0.25	0.70	0.70	0.70
c_2	0.25	0.15	0.15	0.25	0.00	0.60	0.50	0.55	0.40	0.00
c_3	0.10	0.10	0.10	0.25	0.00	0.30	0.00	0.05	0.15	0.00

Source: The author

These results show that, directly or indirectly (global incidence), any cause raised in the SC condition has a minimum level of 0.75 over 1.00.

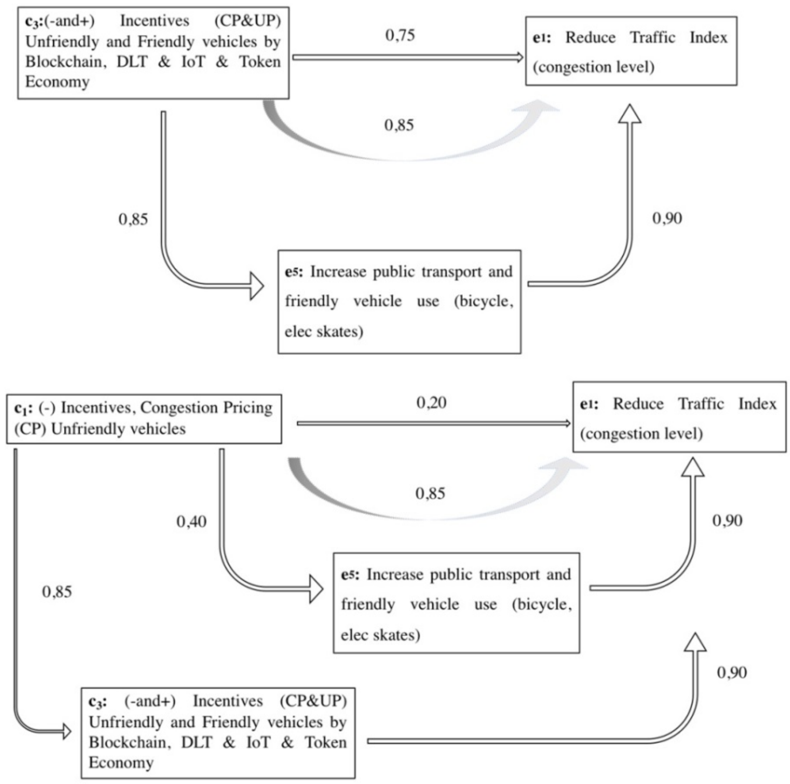
It can be verified that cause c1 has the greatest forgotten effects with a camouflage of its global incidences on the model's effects, particularly for the effects e_8, e_9, e_{10} all with values 0.7 on 1.00.

It is observed that c_1: "(-) incentives, congestion pricing (CP) unfriendly vehicles", is the one that has a less direct impact on "reducing traffic index" indicators e_1=0.20 "productivity improvement" e_2=0.20 and "improving institutions efficiency" e_7=0.55. Progressively, it is observed that c_2: "(+) incentives, uncongestion pricing (UP) friendly vehicles" has more influence on these indicators. When analysing how the cause c_3 affects "(-and +) incentives (CP & UP) unfriendly and friendly vehicles by blockchain, DLT & IoT & token economy", it is verified that the direct affectation is still greater with a significant impact on "reducing traffic index" e_1=0.75, "productivity improvement" e_2=0.75 and "improving institution efficiency" e_7=0.80.

For example, if the effect that c_3 has on "reducing traffic index" is analysed considering only the direct effect (Table 3), then the incidence is 0.75, but if the cumulative effect is observed due to the existence of other interposed variables (Table 6), the effect increases up to the value 0.85. The isolated indirect effect is 0.10 on 1.00 or very low. The interposed effect that intervenes most importantly and that determines that the cumulative effect is maximum is the variable "public transport and friendly alternative" (Figure 2).

At the same time, it can be seen how c_1 is the one with the greatest forgotten effects and following the same example, and its direct impact on the reduction of congestion level (Table 4.3) is 0.20. However, if the accumulated effect is observed due to the impact of the interposed variables (Table 4.6), then its effect increases to the value 0.85. The isolated forgotten effect is very relevant, 0.65 on 1.00. The effect interposed in this case "public transport and friendly vehicle use" explains a part and interposed cause c_3, and its interposed effects would explain the remainder Figure 4.2.

Figure 4.2 Maximum Cumulative Effect in "Reduce Traffic Index" Variable.



Source: The author

Therefore, considering exclusively the direct effects of causes c_1, c_2 and c_3 on the SCMM's variables, the effect on the improvement of congestion level and most of the variables that affect the level of welfare, efficiency and productivity, would be mainly determined from lower to higher incidence for causes c_1, then cause c_2, and finally and with greater impact, cause c_3. In addition, if the forgotten effects are considered, c_1 is the one with the highest values, followed by c_2 and c_3 in this order, which indicates that the direct effect of causes c1 and c_2 is lower if they act in isolation as opposed to intercepting c_3, so provisionally it could confirm the hypotheses H1, H2 and $H3_{1,2}$ of the SCMM.

4.5. Conclusions

The results presented by this exploratory study would allow institutions and organizations to take more effective measures to improve SC mobility and, in particular, to improve urban congestion that is problematic from a broader point of view that includes technological factors and human capital elements when these endpoints are included in the same digital ecosystem creating value and allowing later, through congestion management as a sustainability value, exchange it. The fundamental fact of knowing the direct and indirect effects allows for having very valuable information that is often omitted in decision making. Although any of the three measures proposed in the SCMM influences the SC and citizen welfare, it is observed that the combined technological and human motivation effects (c_3), at the same time, have a provisionally greater impact on improving urban congestion, city productivity, institutional efficiency rather than congestion pricing (c_1) or "uncongestion" pricing (c_2) in isolation.

Most cities and their multiple actors are increasingly aware of the convenience of having an efficient and transparent city management model that encourages citizen participation, while deploying technology use although technology, by itself, does not solve the SC problems. Thus, solutions to major urban challenges require a particular vision, avoiding general technological recipes. In this sense, urban congestion problems (productivity, environment and human health) and solutions need to be approached by not only a digitization umbrella, pursued to win the digital indicators race but also mixing holistic and particular perspective to include others key variables such as human motivational aspect in order to balance externalities and shift urban models ahead from 1.0 to 2.0.

Presently, solutions to the urban congestion phenomena are partial, and as already mentioned, a greener technology, sharing economy or electric or autonomous vehicles incorporation would not solve the traffic density problem and could even have the opposite effect. Fortunately, the digital phenomena allow cities to evolve from the Internet of information to the Internet of value, opening up new possibilities that should be exploited by SC. This disruption will make it possible to exchange intangible things that citizens of a society consider valuable as sustainability. Current and future projections show that people will be living in cities with growth, and as a consequence, tangible and intangible city resources will be scarce, including urban congestion and its negatives effect on productivity, wasted time, health and other issues, consequences that cities will need to manage. Nonetheless, all of these externalities can be digitized as digital externalities such as city digital asset/passive, offering the possibility to exchange them among citizens thanks to available technology (IoT, blockchain, DLT, smart contracts, and tokens). In contrast, adding positive and negative reinforcement incentives for citizens in the equation, will make end-to-end citizen value exchange different and more participatory, distributed, reliable, efficient and transparent formula in a different way such as the tax city institutional predatory perspective, avoiding a centralization mentality.

Thus, institutional roles and industry manager predispositions will play key role in the SC congestion solution. They will need to invest in a long-term vision because cross digital steps such as SCMM are not easy to implement. There is a long path from a centralized, institutional city control to decentralized participation. These new approach flags will allow the incorporation of new rules, adding the possibility to create new intelligent and autonomous city management, configuring a new economy, new scenarios and even new social roles unthinkable until now.

As a limitation of this article, it should be noted that this study is in its first phase (work in progress). At the first moment, we have attempted to test the feasibility of the model to move on to the next phase. However, among other limitations, this paper does not discuss important technologies needed to implement an SCMM such as 5G, artificial intelligence, or big data.

As new areas of research, this study proposes to analyse the SCMM in a large SC are such as Barcelona, in addition to adding new causes and / or effects and even use other methodologies.

Chapter 5

Digital and Programmable Economy Applications: A Smart Cities Congestion Case by Fuzzy Sets

Digital and Programmable Economy Applications: A Smart Cities Congestion Case by Fuzzy Sets[1]

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Abstract. Currently, cities are facing great challenges such as the population growing, citizen wellbeing, externalities management or environmental deterioration. The search for solutions are making significant inroads into the incorporation of ICT in them and subsequent large-scale digitalization such as programmable economy (PE) applications, offering the possibility to develop new approaches over these issues, in particular which related to sustainability management.

Operating under a fuzzy numbers methodology and Fuzzy Inference System (FIS), the present exploratory work shows a new approach to city urban congestion management by deploying PE applications, which include some disruptive inputs such as the Internet of value, blockchain/DLT, smarts contracts, digital assets and the monetization, all of this combined with the human motivation.

Keywords: Programmable Economy, Blockchain, Smart Cities, Urban Congestion, Fuzzy Sets.

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5.1. Introduction

Smart Cities (SC) are moving forward from phase 1.0, or ecosystem connectivity, to phase 2.0, intensifying the decision-making process by involving all the actors that comprise the SC (government, business and residents) with the aim of improving quality of life, increasing competitiveness, promoting sustainability and creating open and inclusive platforms (Ottawa, 2017; Eggers *et al*., 2018; Malone *et al*., 2011). However, what does smart truly mean? The adjective "smart" was born from the ideas of the "Smart Growth Movement" in the 1990s, which was intended to promote new forms of urban planning. Technology companies appropriated this term for the deployment of ICT in cities (Harrison *et al*., 2011). Although there is no definitive consensus on the idea of SC, there seems to be approval on the connection of this term and the use of technology in cities. This deployment is observed because there is growing pressure to improve the efficiency of cities while promoting aspects related to human capital (Perera *et al*., 2014; Gil-Garcia *et al*., 2016). It seems clear that the impact of ICT on better city management is having a transversal impact on all agents (Batty *et al*., 2012), though there is a set of "soft" factors, such as citizen participation, collaboration or reward, that are associated with the objectives of managing resources better, improving services offered or encouraging innovation, and all of them result in an improvement of wellbeing (Cooray *et al*., 2017; Zanella *et al*., 2014; Giudice *et al*., 2011).

These new technologies seek to alleviate or resolve the different facets that occur in a SC, with one of them being the mobility of the subjects and things that happen in a SC. This mobility generates powerful negative externalities, all of which will increase, given that 55% of the world's population currently lives in urban areas and that forecasts for 2050 suggest that this percentage will reach 68% (The World Bank, 2018). Possible future consequences can be considered worrisome. In the case of mobility, possible consequences include pollution, climate change, urban congestion or energy consumption. Cities currently account for 2/3 of the world's energy consumption and are responsible for 70% of greenhouse gas emissions (World Economic Forum, 2018). The charges of massive mobility in SC have a considerable effect on inefficiency. It is estimated that congestion's impact on Gross Domestic Product (GDP) in most cities is 2 to 4% in terms of waste of time or energy and increase in the cost of doing business (Bouton *et al.*, 2015). In the United States alone, congestion costs in cities will increase by 20%, from $160 billion in 2014 to $192 billion in 2020 (Bouton *et al.*, 2017). Regarding this point, many institutions are setting detailed objectives on the efficiency of transport in terms of resources used and the environment, urban congestion, and the formulation of behavioural and social policies on the issue (European Commission, 2017).

The objectives of this paper are, first, to highlight the importance of the digital and PE as a tool to manage externalities. These concepts open up new SC management possibilities and are becoming key elements in formulating future urban strategies, more so if one considers the vertiginous acceleration of the negative externalities that occur in them, particularly those created by urban congestion.

Second, to emphasize the need to focus on the treatment of the current and new threats of SC from a more holistic and inclusive point of view, considering the vital importance that citizens will play in the search for new solutions. The great challenges that tomorrow's SC will face are, to reinforce and promote the active participation of the citizen using the aforementioned opportunity offered by ICT in its different aspects. These technologies should be approached from a vehicular and social integrating point of view to facilitate the better management of the SC and not as ends in themselves.

To elucidate this subject, an exploratory approach to urban congestion phenomena is proposed using the paradigm Structure-Conduct-Performance (SCP) and fuzzy logic to present a new congestion model that uses an inference algorithm that makes it possible to simulate the level of expected congestion in a city based on the combination of the aggregate factors that will be developed in this study, such as the infrastructure and the PE with the use of human reinforcement through the application of citizen' incentives. What is sought is to find the balance between these inputs in such a way that urban congestion can be reduced by deploying the PE as a facilitator tool.

This paper is organized as follows: in section 2, the theoretical background is described. In section 3, the methodology is presented, followed by the results. Finally, section 4 summarizes the most important conclusions of this paper.

5.2. Theoretical Background

5.2.1. Structure: Urban Congestion

The situation of urban congestion worldwide is truly worrying. Taking the Tomtom index (incremental time necessary to make the same journey in traffic jam conditions compared with normal conditions) as a reference, it shows that in such cities as Mexico City, the Tomtom index exceeds 66% (TomTom, 2016). A similar situation occurs in such countries as Thailand, Indonesia, and Brazil that occupy the first positions in the traffic jam ranking provided by INRIX (INRIX, 2017), and the same happens in more developed cities. As already mentioned, the impact of this congestion on their productivity is alarming. The projections for the future are not very promising. With the incorporation of the misunderstood electric vehicle (EV), the idea of "zero emissions" being confused with "zero carbon emissions", the increase in the shared economy, the appearance of autonomous vehicle (AV) and even the increase of commercial vehicles (CV) making home deliveries caused by the increase of e-commerce all added together, it seems that traffic in cities will increase significantly, not decrease (Hahn, 2011; Bouton *et al.*, 2017).

Some solutions are offered in the literature, such as citizens' journey customization on a connected transport network via multimodal solutions (users can choose the best travel option at any time through the incorporation of ICTs and intelligent driving) or the accessibility increasing proximity concept and eliminating the need to move by increasing technology penetration (tele services) (Zielinski, 2012). Some cities are deploying driving prohibitions or limitations for certain types of vehicles (Hamburg prohibits the circulation of the oldest and most polluting diesel vehicles in certain areas and streets) (Europapress, 2018). On the other hand, restrictive measures are implementing via quantities (driving prohibitions on odd or even numbers of alternate days have been adopted in Madrid, Mexico City, Beijing, Bogota, Caracas, and Santiago de Chile). Finally, there are toll initiatives (congestion pricing) where the vehicles that want to access the city's downtown during rush hour must pay, as in Singapore, London, Stockholm, Milan and Gothenburg. This last measure is supported by a recent study about using a congestion pricing viability tax to avoid traffic jams and pollution in large cities (Fageda *et al*., 2018).

Whatever the solution that cities adopt, what seems obvious is that the enormous pressure toward SC efficient urban management is accelerating the use of ICT for finding proper solutions. Among many other technologies behind the ICT concept, today there is one major phenomena, the PE and the concepts underlying it (IoT, blockchain/DLT, monetization, smart contract, and token economy) are revolutionizing the way that people understand and manage cities. These technologies could form new and diverse scenarios of value exchange, both monetary and non-monetary (Gartner, 2015), and allow to take a further step toward PE monetization. Regarding this point, it will be possible to convert urban physical or intangible assets (like urban space or traffic congestion) to digital assets, opening the possibility to create new business management models and revolutionise citizen and city interactions in a transparent and decentralized way.

These technologies will help to improve how cities and citizens coordinate, connect and organize. If cities want to change mobility and congestion, the PE offers new opportunities.

5.2.2. Conduct: Citizen's Reinforcement

ICT measures, in some way, are contributing greatly to better mobility and a reduction of urban congestion; however, considering citizen habits as a basis, these measures are not sufficient. In this way, looking for a better resource combination and mobility and congestion solution could be accelerated through a better combination of digital technology and PE, which are then all together joined with citizen reinforcement, encouraging a change of habits. Tomorrow's cities (SC 2.0) are looking to provide a positive citizen and visitor experience, and they need to contemplate how to motivate them in their equation.

The move of cities' visions from "car-centric", anchored in the 1920s-30s, to "people-centric" (walking, riding, cycling or using public transportation) needs to be reinforced (World Economic Forum, 2015). Therefore, there could be used some factors beyond the technological and economic ones, such as human reinforcement and motivation, in order to stimulate and involve citizens in congestion resolution.

Learning theory (Skinner, 1953) or reinforcement theory refers to the stimuli used to produce desired behaviours. B.F. Skinner argues that the administrator only needs to understand the relationship between behaviours and their consequences in order to create conditions that encourage desirable behaviours and discourage undesirable ones. This appreciation could be used in urban city management to motivate citizens and support or dissuade their mobility conduct through negative incentives (congestion pricing, CP) applied to (private and commercial) unfriendly vehicles, and positive ones (uncongestion pricing, UP) applied to friendly vehicles in a particular area, all of which can contribute to better mobility in cities.

It is important to mention that the friendly or unfriendly vehicles classifications have been defined regarding urban transport environments' impact in developed countries according to their efficiency in terms of respecting the environment while minimizing the impact on the climate of greenhouse gases (CHG), (World Health Organization, 2011), 1-Unfriendly: 61-170 max Co2-eq emissions/passenger by travel (-gasoline, diesel, electric-cars, motorbike, vans, trucks, coach). 2-Friendly: 25-60 max Co2-eq emissions/passenger by travel (bicycles, scooters, public transport-train, metro, bus).

5.2.3. External Conditions: Programmable Economy

In what way can SC combine technological advances with citizen reinforcement deployment such that they are encouraged to use minor polluting vehicles at the same time that city hall is allowed more efficient, rapid and transparent management over all this?

PE will be the answer. The PE concept was introduced by Gartner in 2014 to refer to an intelligent economic system that supports and, at the same time, manages the production and consumption of goods and services, making possible new exchanges of value (monetary and nonmonetary) (Gartner, 2015). PE is supported through blockchain or DLT, IoT, monetization, token economy, smart contracts, artificial intelligence and cryptography, thereby supporting new forms of value exchange, new types of markets and new forms of the economy. In this PE, it will be the individuals and the smart machines that will define the value and determine how the exchanges will be determined through peer-to-peer transactions involving organizations and even smart machines and agents. The PE permits the creation of new business models by combining the physical world with the digital one, allowing predictions regarding behaviour to be made while changing the ways in which value is exchanged. The PE's implications include removing the middleman, imagining new ways of exchanging the value of the tangible and intangible between people and institutions, rethinking new forms of governance relationships, allowing greater automation by minimizing external oversight and decentralizing the economy and managing information better. However, perhaps one of the greatest characteristics of the PE is the possibility of monetizing things and services by redefining the economy and the way in which value is exchanged between intelligent physical or intangible things and citizens (Sloan, 2018), enabled by the second generation of the internet; that is, through Web 2.0 going from an "Internet of information" to an "Internet of value", radically changing the operation of the economy and of institutions (Tapscott, 2017).

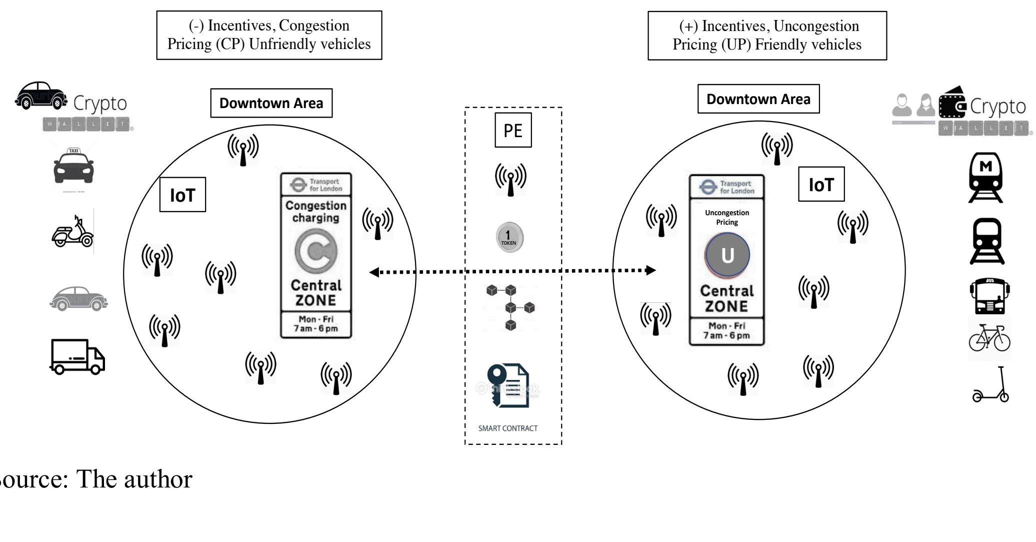
PE technology drastically reduces the cost of trust and allows to imagine new business models and opens the possibility of deploying new forms of collaboration at the same time. As a source of trust, PE can expand organizations' and institutions' degree of DT whereby they can share processes among all actors. All of this is possible due to the fact that this technology makes the information contained within it immutable, safe, shared and consensual (Harvard Business Review, 2017).

On the other side, PE by smart contracts or intelligent contracts, a concept attributed to Nick Szabo (Szabo, 1996) in 1996, facilitates the agreement of individuals, organizations and institutions in such contracts over how they want their business or public services to be carried out in a consistent and automated manner, keeping participant interactions recorded in a transparent manner at all times. This technology allows better decision-making between people or between machines without human intervention.

In addition, one of the most important characteristics of PE technology is that it allows the reduction, in a very consistent manner, of the so-called “transaction costs” defined in Coase's work, “The Nature of the Firm" (Coase, 1937). These costs include the cost of organization, negotiation, information monitoring and coordination (Potts *et al.*, 2017), and digital technologies can clearly reduce many of these costs. PE technology tends to reduce decisions and many coordination functions could be replaced by software, opening new institutional possibilities in order to reduce transaction, control, and monitoring costs and give them the possibility to achieve more efficient data coordination.

Thus, PE allows a strong impulse toward connected mobility by using IoT, DLT, smart contracts, tokens and digital wallets in all kinds of vehicles. In this way, if it is wanted to decongest a specific area of the city, the city’s administrators could define a space (downtown area) in which there would be an exchange of externalities between friendly and unfriendly vehicles through the use of incentives and PE. Thus, the unfriendly vehicles that are mentioned before, can make certain token transfers automatically to city hall and friendly vehicles in order to pay congestion charges (congestion pricing) to accessing a specific city area, and friendly vehicles can receive them as shown in figure 5.1:

Figure 5.1 Downtown Congestion Framework



Source: The author

In other words, if city resources, such as space, are limited, then friendly and unfriendly vehicles (vehicles that cause urban congestion and its negative externalities, such as contamination, noise, and accidents) have a new way to compete for the city's scarce resources using the reinforcements' monetization. In this sense, friendly vehicles (and their owners) can obtain the positive incentives (uncongestion pricing) delivered by the PE if they have access to the same area by a more sustainable mode, such as receiving part of the congestion pricing paid by unfriendly vehicles in the same area. The form of this transaction from unfriendly to friendly vehicles is possible through PE and tokens and can be related to stable coins (Luginbühl, 2018). After that, friendly income can be exchanged for public transport discounts, payment of local taxes, commerce coupons in the congested area or users can exchange it for fiat money too, all with minimal human interaction.

Also, a part of this charge received by city hall can be reinvested directly in maintaining and constructing new city infrastructure.

Therefore, PE by spill-over effects' monetization when sustainability such as congestion, is managed as a value by the agents (Elkington, 2004; United Kingdom Green Building Council, 2018), activates the possibility to deploy the digital asset concept (a digital asset market representing the physical assets, such as vehicle space in cities). In other words, through PE technologies it is possible to create a new city congestion scenario to manage and negotiate access for any vehicle to a specific area, motivating citizens through positive or negative incentives and dissuading the use of unfriendly vehicles and encouraging the use of friendly ones, such as public transportation or bicycles. On the other hand, PE applied to the institutional administration becomes an excellent technology for governance, decentralization and information systems. All of the above can have an impact on productivity and organizations' efficiency and will be extremely beneficial for them (Davidson *et al*., 2018).

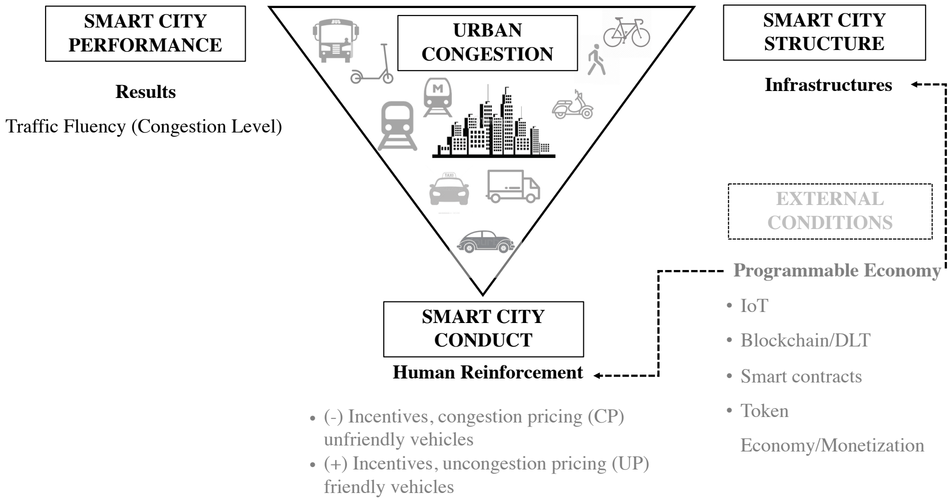
In view of the above explanation, and to put all of these concepts in order, a new approach to urban congestion phenomena is presented using the Structure-Conduct-Performance (SCP) paradigm formulated by Mason and Bain.

This model states that the structural characteristics of the market determine the behaviour of agents and, in turn, their behaviours determine their outcomes. The SCP paradigm assumes that the structure of the market determines the conduct of the firms and these determine the results (Bain, 1956). The concept of market structure is the set of characteristics that influence the behaviour and results of the agents that operate in it, and public policies would have a high impact on this structure (Weiss, 1971; Neuberger, 1997). On the other hand, the conduct refers to the behaviour patterns followed by the firms that operate in the market (Bain, 1956). These patterns include the behaviours or actions of the agents (citizens), and these conducts are determined by the characteristics of each industry (city mobility). Finally, the results of the market (city congestion level) are the product of the combination of its structure and its conduct. Also, if it is wanted to have a big SCP picture it is needed to add external conditions, such as socioeconomic factors, governmental policies and, in particular, the digital aspects of ICT. ICT plays a transcendental role in this model by conditioning the market, because any variation in ICT can cause changes in the model (Canback, 2018). The measurement of these results can be determined in the form of benefits, profitability or efficiency related to the resources used (Neuberger, 1997).

Taking the SCP model as reference, it is proposed that the solutions to the congestion problem become more holistic and include, in addition to the different functions of Batty's SC (Batty *et al*., 2012), the combination of the external factors generated by digitalization and the PE, along with aspects related to behaviour, such as human reinforcement and the use of incentives (positive or negative congestion pricing depending on whether a friendly or unfriendly vehicle is owned), can change the game. All of this is contemplated in the SCPUCOM (Structure-Conduct-Performance Urban Congestion Model). SCPUCOM is modelled as a digital ecosystem, a set of functional niches and roles, a set of elements located within a complex whole in which each niche fulfils a particular function sharing standardized digital platforms (Rynn, 2007; Gartner, 2017) and as presented in Figure 5.2.

Following the SCPUCOM, a city's performance is produced as a consequence of the city's structure and conduct. At the same time, the results can also be affected by variations in external city conditions if conducts' and structure factors are managed by digital ecosystem and PE.

Figure 5.2 SCPUCOM Model.



Source: The author

In this sense, placing the focus on urban congestion is difficult, and it is proposed to exclusively address the principal externality that it generates. The main objective will be to increase traffic fluency in downtown areas, although the list of results, not treated here, would be expandable to others – improve city productivity (reduce waste of time due to traffic), improve the environment (more green areas and less noise/Co2 pollution), improve health (reduce personal stress, related diseases, and accidents) increase public transportation and friendly vehicle use (bicycles, electric skates), improve local financial resources, increase institutional governance efficiency (reduce transaction and monitoring costs), increase connectivity and networking (digitalization), increase citizen participation (P2P, Apps) and build the backbone to deploy others digital assets (reward citizen behaviour) – not developed in this article.

The problem that is required to solve revolves around knowing to what extent the modification of the conduct factor by congestion incentives combined through PE technology reduce urban congestion and what kind of importance has the city structure in order to apply these initiatives. Specifically, it is necessary to know whether the deployment of the PE, together with the implementation of positive and negative incentives on the use of friendly and unfriendly vehicles in a defined area of the SC, can alter traffic levels more than if there are used only positive and negative incentives without PE to maintain city structural fixes.

In the search for such results, there are no simple solutions, since inaccuracy and uncertainty act within cities. In addition, certain parts of the proposed urban mobility system are unknown, and cannot be measured reliably without clear limits on the concepts of structure, conduct and the external factors that occur in cities. For this reason, what is proposed is to make use of fuzzy systems methodology to reproduce reality more faithfully and to relax the restrictions because there are concepts that have no clear limits. Therefore, it is used fuzzy science in order to find an algorithm to understand if citizen reinforcement measures, such as congestion and uncongestion pricing deployed in particular areas, reduce a city's traffic and what would be the better way to deploy it, with PE or without it.

5.3. Methodology

5.3.1. Fuzzy Sets

The theory of fuzzy sets was introduced in 1965 by Lofti A. Zadeh. The idea resides in the fact that the elements that make up human thought are not numbers but linguistic labels. According to the principle of incompatibility as the complexity of a system increases, the ability to be precise decreases to the point that precision and meaning are exclusive characteristics (Zadeh, 1975). From this idea, fuzzy logic allows to represent common thought in a mathematical language based on the theory of fuzzy sets and their characteristic functions. Fuzzy logic's applications have increased to the point of being considered a real revolution, developing a large number of extensions, such as soft computing that covers the fuzzy sets and fuzzy logic for approximate reasoning and the theory of possibility (Merigó-Lindahl, 2009).

According to this theory, it is been considering a referential set or universe of discourse, U, and an ordinary subset, $A \subset U,$ of those elements that fulfil a specific characteristic. For ordinary subsets there are only 2 possibilities, $\forall$

$x \in U$: "x" satisfies the characteristic *($x \in A$)* or "x" does not comply ($x \notin A$). Therefore, the membership function of A is defined:

$$\forall x \in U \; \mu_A(x) = \begin{cases} 1 \; if \; x \in A \\ 0 \; if \; x \notin A \end{cases}$$

An ordinary subset of $A \subset U$ is symbolized by the pair $(U, \mu_A(x))$.

Now, if the elements of A can take any value in a range [0, 1], it could be said that there are elements of U that fulfil the characteristics defined in subset A, but only to a certain degree. In this sense, the membership function of A will be defined as,

$$\forall x \in U:$$
$$\mu_A(x): U \rightarrow [0,1]$$
$$X \rightarrow \mu_A(x) = \alpha \in [0,1]$$

In this way it is possible to construct a fuzzy subset $(U, \mu_A(x))$ symbolized by $A \subset U$.

$$A = \{(x, \mu_A(x)) \,/\, x \in U\}$$

On the other hand, fuzzy logic allows the assignment of linguistic values to the variables of a problem, similar to the evaluation of a parameter usually conducted by people, whether they are experts or not (Zimmermann, 1987; Jones, 1994).

In this sense, the universe of discourse is the range of possible values for an input to a fuzzy system. A fuzzy set is any set that allows its members to have different grades of membership (membership function) in the interval [0,1]. Linguistic variables are the input or output variables of the system whose values are words or sentences from a natural language, instead of numerical values. A linguistic variable is generally decomposed into a set of linguistic terms.

5.3.2. Mandami Fuzzy Inference Systems

There are two well-known rule-based fuzzy inference systems (FIS), the Mandami fuzzy method (Mandami *et al*., 1975) and the Tagaki Sugeno (T-S) fuzzy method (Takagi *et al*., 1985). The main idea of the Mandami method is to describe process states by means of linguistic variables and to use these variables as inputs to control rules. The Mandami fuzzy model involves developing membership functions and defining the subsequent rules. The rules connect the input variables with the output variables and are based on the fuzzy state description that is obtained by the definition of the linguistic variables.

The basic components of a Mandami Fuzzy System (Mandami, 1977) are the following: fuzzification, a knowledge base with an inference system and defuzzification. Meanwhile, the general structure of a fuzzy model includes the input variables, the development of rules and the output variables.

i. Fuzzification, understood as the introduction of input values and their interpretation as linguistic values, determines the membership functions of the system variables in the fuzzy sets. The universe of discourse of each variable was determined by the linguistic components for input and for output. A fuzzy set is defined by the expression below:

$$A = \{(x, \mu_A(x)) \;/\; x \in U, \mu_A(x) \in [0,1]\}$$

where U represents the universal set, x is an element of U, A is a fuzzy subset in U and $\mu_A(x)$ is the membership function of fuzzy set A.

ii. The knowledge base consists of fuzzy rules defined with the help of experts. A single fuzzy if-then rule assumes the form:

If x is A Then y is B

where A and B are linguistic values defined by fuzzy sets in the range (universe of discourse) x and y, respectively. The "x is A" part of the if-then rule is called the antecedent or premise, while the "y is B" part of the rule is called the consequent or conclusion (Yuanyuan *et al*., 2009). During data processing, a fuzzy system fuzzifies the crisp data and applies the Mandami inference system using the fuzzy rules (by experts). In this study, the fuzzy control rules are of the form

R_i: $If\ X_1\ is\ A_i^1\ and\ \ldots\ and\ X_r\ is\ A_i^r\ Then\ Y\ is\ C_i$

where the variables $X_j, j \in \{1,2,\ldots,r\}$, and Y have the domains U_j and V_j, respectively. The firing levels of the rules, denoted by $\{\propto_i\}$ are computed by

$$\propto_i = T\ (\propto_i^1, \ldots, \propto_i^r)$$

where T is a t-norm and $\propto_i^j$ is the firing level for $A_i^j, j \in \{1,2,\ldots,r\}$. The causal link from $X_1, \ldots, X_r$ to Y is represented using an implication operator, I.

This results in the conclusion C'_i inferred from the rule R_i being

$$\mu_{C'_i}(x) = I\left(\alpha_i, \mu_{C_i}(x)\right), \forall x \in U$$

and using Mandami implication *I* the formula is

$$\mu_{C'_i}(x) = I_M\big(\alpha_i, \mu_C(x)\big) = \min\{\alpha, \mu_C(x)\}.$$

The final output of the model is the aggregation of outputs from all rules using the max operator:

$$\mu_{C'}(x) = \vee_{i=1}^n \left[\alpha_i \wedge \mu_{c_i}(x)\right] = \vee_{i=1}^n \mu_{c'_i}(x)$$

iii. Defuzzification is used to obtain an output from the previous fuzzy set. A centroid method is usually used. Subsequent defuzzification produces a crisp value output. Defuzzification uses some methods, such as centre of gravity or centroid (COG), mean of maximum (MOM), and first of maximum (FOM). Centre of gravity is the most popular and the most precise method used for defuzzification. The centre of gravity method is a grade weighted by the areas under the aggregated output functions. The formula for the centroid is given as

$$\text{COG} = \frac{\int \mu_c(x) x dx}{\int \mu_c\,(x) dx}$$

where $\int \mu_c\,(x)dx \neq 0\; for\; all\; \mu_i$

5.3.3. Fuzzy Inference System to Estimate Urban Congestion

This section introduces a Fuzzy Inference System Urban Congestion (FISUC) to estimate urban congestion by algorithm. The objective of the proposed algorithm is to provide the urban congestion function of a city based on the input given as structure (infrastructure), conduct (negative incentives in the form of congestion pricing for unfriendly vehicles and positive incentives in the form of uncongestion pricing for friendly vehicles) and an external factor (programmable economy). The linguistics variables, fuzzy set and universe of discourse are given in Table 5.1 and Table 5.2:

Table 5.1 Linguistic Variables

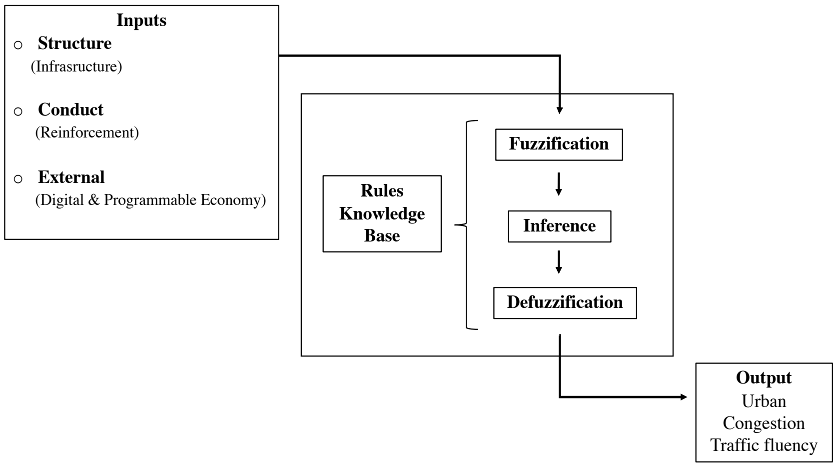
Structure (S)	Conduct (C)	External (E)	Congestion (CO)
-City Infrastructure.	(-) Incentives, Congestion Pricing (CP) Unfriendly vehicles. (+) Incentives, Uncongestion Pricing (UP) Friendly vehicles.	-Programmable Economy (IoT, Blockchain, DLT, smart contracts, monetization and token economy)	-City traffic level
Source: The author			

Table 5.2 Fuzzy Set and Universe of Discourse

Linguistic Variabl	Fuzzy Set	Universe of Discourse
Structure (S)	$A_s = \{x, \mu_s(x) \,/\, x\epsilon[0,100]\}$	$U = [0,100]$
Conduct (C)	$A_C = \{x, \mu_C(x) \,/\, x\epsilon[0,100]\}$	$U = [0,100]$
External (E)	$A_E = \{x, \mu_E(x) \,/\, x\epsilon[0,100]\}$	$U = [0,100]$
Congestion (CO)	$A_{CO} = \{x, \mu_T(x) \,/\, x\epsilon[-100,0]\}$	$U = [-100,0]$
Source: The author		

Figure 5.3 shows a block diagram of the proposed FISUC algorithm (urban congestion), which includes a fuzzification block, a knowledgebase, a fuzzy inference engine and a defuzzification block.

Figure 5.3 FISUC Algorithm.



Source: The author

The proposed algorithm consists of three steps: fuzzification, fuzzy rules, and defuzzification.

Step1 – Fuzzification: in order to keep the number of fuzzy rules at a reasonable level, input can be defined as fuzzy set levels with three membership functions known as “Low”, “Medium” and “High”. For the output, the congestion (city traffic level) fuzzy set has three membership functions, such as “Jam”, “Dense”, and “Fluid”.
To define the structure, conduct and external membership functions, it is used the Global Competitive Index Report 2017-2018 (World Economic Forum, 2018) sub index approach, including their “basic requirement” sub index (institutions, infrastructure, macroeconomics, and environment), “efficiency enhancer” sub index (higher education, high efficiency, labour market efficiency, financial market, and technological readiness), and “innovation and sophistication” sub index (business sophistication and innovation), respectively behind a universe of discourse valued between 0 and 100. To obtain the congestion membership function, it is used the TomTom Congestion Index (increase in overall travel time when compared to a free float situation or uncongested situation) (TomTom, 2016) approach as a close reference in a universe of discourse valued between -100 and 0.

It is divided the initial linguistic variables where each has their own appropriated linguistic values defining the fuzzy set membership function, as explained in Tables 5.3, 5.4, 5.5 and 5.6.

Table 5.3 Structure Membership Function

Linguistic Variable	Functions
Low (L)	L Function: $1-\mu_x=\begin{cases}0 & if\ x\le 38\\ \frac{x-38}{57-38} & if\ x\in(38,57)\\ 1 & if\ x\ge 57\end{cases}$
Medium (M)	Triangular Function: $\mu_x=\begin{cases}0 & if\ x\le 45\\ \frac{x-45}{62-45} & if\ x\in(45,62)\\ \frac{78-x}{78-62} & if\ x\in(62,78)\\ 0 & if\ x\ge 78\end{cases}$
High (H)	L Function: $1-\mu_x=\begin{cases}0 & if\ x\le 64\\ \frac{x-80}{80-64} & if\ x\in(64,80)\\ 1 & if\ x\ge 80\end{cases}$

Table 5.4 Conduct Membership Function

Linguistic Variable	Functions
Low (L)	L Function: $1-\mu_x=\begin{cases}0 & if\ x\le 35\\ \frac{x-35}{45-35} & if\ x\in(35,45)\\ 1 & if\ x\ge 45\end{cases}$
Medium (M)	Triangular Function: $\mu_x=\begin{cases}0 & if\ x\le 35\\ \frac{x-35}{60-35} & if\ x\in(35,60)\\ \frac{85-x}{85-60} & if\ x\in(60,85)\\ 0 & if\ x\ge 85\end{cases}$
High (H)	L Function: $1-\mu_x=\begin{cases}0 & if\ x\le 75\\ \frac{x-75}{85-75} & if\ x\in(75,85)\\ 1 & if\ x\ge 85\end{cases}$

Table 5.5 External Membership Function

Linguistic Variable	Functions
Low (L)	L Function: $1-\mu_x=\begin{cases}0 & if\ x\le 30\\ \frac{x-30}{46-30} & if\ x\in(30{,}46)\\ 1 & if\ x\ge 46\end{cases}$
Medium (M)	Triangular Function: $\mu_x=\begin{cases}0 & if\ x\le 40\\ \frac{x-40}{60-40} & if\ x\in(40{,}60)\\ \frac{60-x}{85-60} & if\ x\in(60{,}85)\\ 0 & if\ x\ge 85\end{cases}$
High (H)	L Function: $1-\mu_x=\begin{cases}0 & if\ x\le 75\\ \frac{x-75}{90-75} & if\ x\in(75{,}90)\\ 1 & if\ x\ge 90\end{cases}$

Table 5.6 Congestion Membership Function

Linguistic Variable	Functions
Jam (J)	L Function: $1-\mu_x=\begin{cases}0 & if\ x\le -50\\ \frac{x-(-50)}{-30-(-50)} & if\ x\in(-50,-30)\\ 1 & if\ x\ge -30\end{cases}$
Dense (D)	Triangular Function: $\mu_x=\begin{cases}0 & if\ x\le -35\\ \frac{x-(-35)}{-22-(-35)} & if\ x\in(-35,-22)\\ \frac{-10-x}{-10-(-22)} & if\ x\in(-22,-10)\\ 0 & if\ x\ge -10\end{cases}$
Fluid (F)	L Function: $1-\mu_x=\begin{cases}0 & if\ x\le -15\\ \frac{x-(-15)}{-5-(-15)} & if\ x\in(-15,-5)\\ 1 & if\ x\ge -5\end{cases}$

Source: The author

Step2 – Fuzzy Rules: in this step, it is used linguistic quantification to specify a set of rules that captures the experts' knowledge about how to control the output.

To be able to determine which the rules to apply to the model are, two SC experts (Public Administration and Private Enterprise) were asked through personal interviews to carry out the rules.

It is important to mention that this project has been divided into two phases: In a first phase, it is tested the model with two SC experts to later introduce their acquired learning, then go to phase two and extend the number of experts to 10 in the fields of: institutional, technology, blockchain, urban planning, public transportation, private sector, automotive industry, commerce and academics.

The interview methodology started by explaining the model, then experts completed some matrix in order to establish the importance of structure, conduct and external issues in urban traffic congestion, thereby establishing the rules given in Table 5.7.

Step3 – Defuzzification: the inputs for the fuzzy system introduced in this study were structure, conduct and externalities, all of which are crisp. Initially, the fuzzy system fuzzifies the crisp data and then, with the Mandami inference system, applies the fuzzy rules. Finally, using COG, it is determined the congestion output (city traffic level).

Table 5.7 Rules (Knowledge Base)

Rule	If Structure	And Conduct	And External	Then Congestion
1	H	H	L	D
2	H	M	L	D
3	H	L	L	D
4	H	H	M	F
5	H	M	M	F
6	H	L	M	D
7	H	H	H	F
8	H	M	H	F
9	H	L	H	D
10	M	H	L	D
11	M	M	L	J
12	M	L	L	J
13	M	H	M	F
14	M	M	M	D
15	M	L	M	J
16	M	H	H	F
17	M	M	H	F
18	M	L	H	D
19	L	H	L	J
20	L	M	L	J
21	L	L	L	J
22	L	H	M	D
23	L	M	M	F
24	L	L	M	J
25	L	H	H	D
26	L	M	H	D
27	L	L	H	J

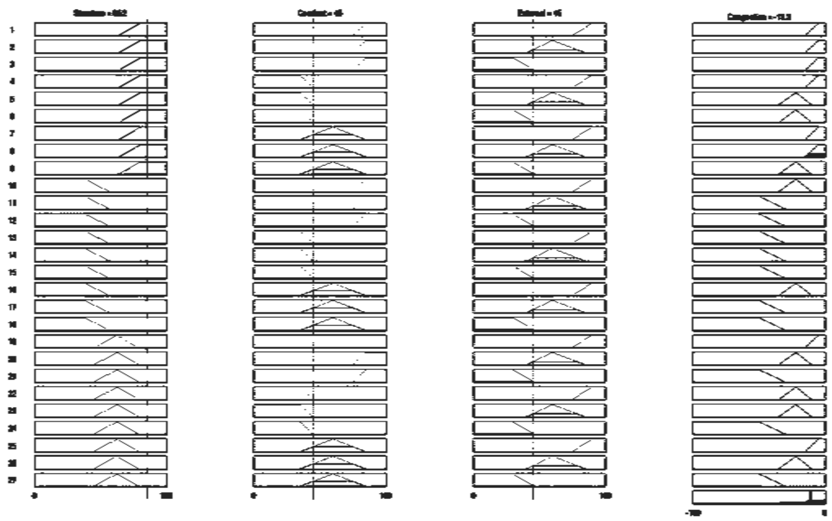
Source: The author

5.4. Results

Figures 5.4 and 5.5 show the output of the fuzzy inference system in the Matlab (Toolbox Fuzzy Logic Matlab) (Matlab, 2018), software for the prediction of urban congestion. For example, if the values of input variables for a particular city -i.e., structure (infrastructure), conduct (incentives) and external (PE)- are 85.2, 45 and 45 respectively, then the membership functions profile is shown in Figure 5.4. The values of output variables (i.e., congestion) would be -11.3, belonging to the dense language variable.

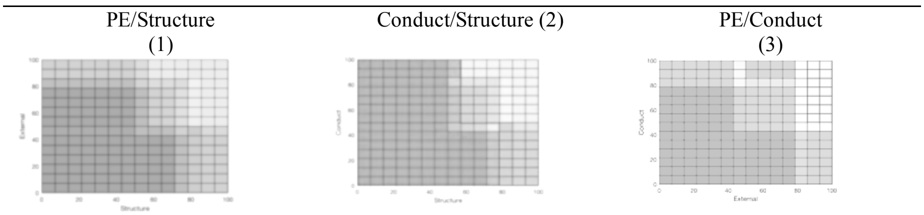
Controlling levels between input structure variables with IF-THEN are presented in Figure 5.5 (dark, grey and white areas represents jammed, dense and fluent traffic, respectively). As shown, congested traffic decreases as the structure – horizontal axis – and PE – vertical axis – increase for any given level of structure, with its effects being more noticeable if the structure is larger (1). In this way, the intensive use of PE from a certain level of structure has a greater impact on the reduction of congestion levels. On the other side, actions carried out through initiatives on conduct – vertical axis – (positive and negative incentives) alone to reduce the level of congestion are more limited to certain levels of city structure – horizontal axis– (2). In other words, at the same level of structure, the expected results are greater if the two inputs (conduct plus PE) are combined at the same time. In this way it is clear that the joint effect of conduct through the deployment of PE on the reduction of congestion is greater (3).

Figure 5.4 Membership Functions Example from Matlab.



Source: The author

Figure 5.5 Control Levels between Inputs and Outputs (Matlab).



Source: The author

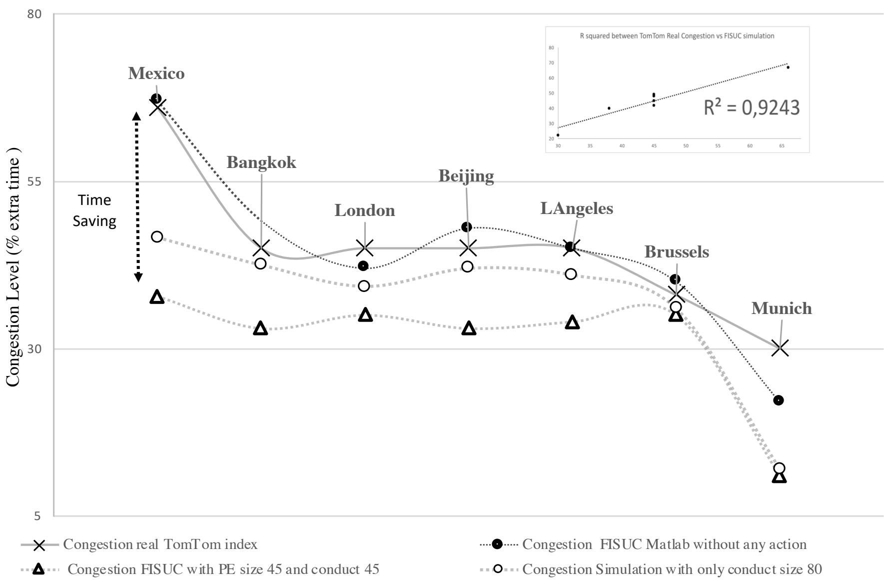
The analysis diagram of the sensitivity of empirical data from the TomTom Traffic Index vs the values predicted by the fuzzy inference system urban congestion (FISUC) simulation data in several cities (Mexico City, Bangkok, London, Beijing, Los Angeles, Brussels and Munich) with different levels of inputs are revealed in absolute values in Table 5.8 and in graphic version in Figure 5.6.

Table 5.8 Fuzzy Inference System Urban Congestion (FISUC)

City	TomTom Real Traffic Congestion Index 2018	FISUC (1) (Absolute) S=City level C=0, PE=0	FISUC (2) (Absolute) S=City level C=45, P=45	FISUC (3) (Absolute) S=City level C=80, PE=0
Mexico	66	67	37	46
Bangkok	45	49	33	42
London	45	42	35	39
Beijing	45	48	33	42
L.Angeles	45	45	34	41
Brussels	38	40	35	36
Munich	30	22	11	12

Source: The author

Figure 5.6 Congestion Examples (Real vs FISUC) by Cities



Source: The author

As can be seen in Figure 5.6, there is a good correlation between the TomTom traffic index (real) and the congestion simulation –FISUC (1) – with $R^2 = 0.924$, which is notably high. On the other hand, also shows the greatest potential savings of time is obtained if the deployment of the variable conduct and PE were carried out at the same time –FISUC (2)– and not conducted in isolation –FISUC (3)–, keeping the structure variable (infrastructure) constant.

5.5. Conclusions

The results presented by this exploratory study would allow institutions and organizations to take more effective measures to progress aspects related to SC mobility and, in particular, to improve urban congestion problems from a broader point of view that includes, first, all agents in the same digital ecosystem and subsequently manage congestion as a sustainability value using for it PE and human reinforcement elements. On the one hand, when these endpoints were included in the same digital ecosystem, sustainability value creation has advanced and, on the other when PE has been deployed, it has encouraged the possibility to capture it, exchange it and distribute it. The integration of these two perspectives in a single and ad hoc frame means to interweave reliably digital and programmable value based economy and management.

To achieve objectives a knowledge base has been acquired through a group of SC experts and representative organization indicators have been used to calibrate the membership functions of the input and output variables.Through this knowledge, it was possible to extract the linguistic variables and their rules, making it possible to build a diffuse inference system. Also, this system has been tested using the Fuzzy Logic Toolbox from Matlab.

In this research, the objective of which is to reduce the negative externalities generated by urban mobility (congestion), used fuzzy systems (Mandami inference) for the diagnosis of urban congestion considering some inputs (infrastructure, conduct and PE) and regarding SCP paradigm and the reinforcement theory. These inputs are not exhaustive of the complex urban mobility system, but they have a large impact on it. It is been observed that by using the FISUC algorithm and keeping the urban infrastructure variable constant by each city, the impact of deploying an incentive base that rewards sustainable mobility and discourages the use of less sustainable vehicles through PE technology is greater than if it was done in isolation, presenting both options a high impact in terms of traffic reduction and drivers' time savings. The benefits of the application of the proposed fuzzy inference system may vary depending on the initial level of infrastructure. Regarding this point, it is been observed that there are limitations in the city "structure" affecting the ability to take advantage of the benefits of the other inputs. In this sense, the deployments of incentives require a medium level of structure to be effective. Therefore, cities without a minimum level of infrastructure should prioritize investing in it first to subsequently reach a certain level of infrastructure that allows them to capitalize other initiatives. Likewise, from a certain level of city structure (medium-high), the best initiatives to reduce congestion levels go through the application of incentives on behaviour and the PE at the same time, and do not focus so much on improving the infrastructure only. Initial city infrastructure level is a key aspect to assess the application of more advanced initiatives. So, developed SC can start and deploy PE's initiatives, meanwhile early cities developers need to invest and improve their infrastructures firstly in order to achieve structure tipping point that permit them to take off and, after that, combine with PE and take advantage of it. In this way, it cannot be affirmed that the same level of infrastructure corresponds with the same level of congestion because there are specific variables of each city that are very important, such as geographic density or economic centres and jobs locations.

In this article, it is also wanted to highlight the possibility of exploring the treatment of other externalities generated in cities through the PE as the congestion issue was treated in this article. The set of concepts that this technology includes, all of them together, will be of vital importance in the future. Pushing citizens' participation in city decision-making at the same time in transparent, reliable, monetized, peer-to-peer and decentralized manner to open a new way for urban managers to explore externalities or other issues. In no case is this study intended to relegate the role of institutions, but to the contrary seeks to provide them with technological capabilities to find new modes of fairer management efficiency and dissuade citizens from generating negative footprints and encouraging them to contribute to generating a more sustainable city.

As limitations of this article go, it should be noted that this approach is in its first phase. At this moment, this research has only attempted to test the feasibility of the model in order to move on to the next phase. On the other hand, as for other limitations, this paper does not talk about the important technologies needed in order to implement the PE, such as 5G, artificial intelligence, big data, the machine to machine economy or cryptography. Also, this article does not include other variables of great relevance and very high impact included in the SCP paradigm for cities, such as legal aspects, taxes, user profiles, government policies and many more.

As part of future research, it is planned to add new variables to the proposed system such as monetary or non-monetary incentives, multimodal transport tickets and tele-services penetration in cities because, as it has been seen in theoretical background section, all of them are being testing in some cities and data could be available for it study. On the other hand, it could be analysed other results derived from this work, such as the impact of reduced congestion on SC productivity or its effects on citizens’ health, or open up the possibility to apply PE and diffuse systems to the treatment of other urban externalities like waste recycling or unhealthy consumption.

Chapter 6

Sustainable City by Connecting Critical Endpoints

Sustainable City by Connecting Critical Endpoints *

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Abstract. Uncontrolled global economic growth at any price is having palpable and general consequences for Smart City (SC) environments and sustainability worldwide. The current economic growth model is, according to experts, decidedly unsustainable, and if urgent measures are not taken, the quality of life for future citizens will decline. In the search for solutions that would make cities sustainable, the deployment of the ICT factor is playing a decisive role. However, in its role as a driver, the ICT factor needs to increase the numbers of endpoint connectors by incorporating citizens, corporations and institutions into city decision-making, thereby becoming a real integrative tool that achieves sustainability and being more than merely a tech flag. In this sense, the present paper proposes that the digital and programmable economy should become a city's backbone to increase sustainability levels through, for example, municipal recycling. This paper will apply the environment-social-economy model and fuzzy logic.

Keywords: Programmable Economy, Sustainability, Smart Cities, Recycling, Fuzzy Sets.

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6.1. Introduction

In recent years, starting with the Kyoto Protocol (United Nations, 1997) and including the Paris Agreement COP21 (European Commission, 2015), there is an increasing awareness of issues related to climate change and the sustainability of the planet. To put the dimension and scope of these phenomena into a global context, it is estimated that the cost and risk of inaction to the global economy could reach 5% of the planetary GDP each year, reaching up to 20% total. This situation could be reversed if only 1% of the global GDP were invested in activities that mitigated climate change each year (Stern, 2007). Moreover, the effects of globalization in all its extremes have spread. The Western way of life and set of socialized needs have spread throughout the five continents, encouraging developing countries to imitate the lifestyles of the developed nations. As a consequence, according to experts, if the effect of technology on development is maintained constantly, between 1.5 to 8 planets similar to Earth would be needed to offer the same level of quality of life and to supply all the new consumers at the same pace as that exists in developed countries (Wilson, 2003).

These developments are forcing different social and economic agents to reconsider the need to make drastic changes in productive processes and in citizens' consumption habits due to the ecological and physical limitations that these developments impose both globally and locally, thereby inviting the questioning of the current and future welfare model. In this sense, Smart Cities (SC) are not alien to this transformation, and their future will require measures to strengthen the sustainability of cities. If the current trend continues, there is a strong possibility that these cities will be unable to support a minimum level of wellbeing for their future citizens (Ahford *et al.*, 2018).

To try to reduce this imbalance, cities will no doubt become increasingly unique players in promoting sustainability, since they constitute an important centre of origin and a destination for many of the negative externalities that are affecting the sustainability of the planet. In searching for solutions, it should be noted that countries and SCs themselves cannot focus their efforts on a single discipline or address the new challenges solely and exclusively from a technological point of view. Promoting sustainability requires an interdisciplinary approach to help understand the problem of sustainability for the subsequent formulation of solutions because there are important interconnections between elements that exist beyond the technological ones that need to be put into context to achieve a truly sustainable transformation.

These solutions should include the design of holistic and integrated policies, taking a step beyond pure coordination with more transversal approaches (Costanza *et al.*, 1991). Undoubtedly, the deployment of technology and DT will play a key role in SCs as a backbone of multidisciplinary integration.

Although there is no definitive consensus on the idea of an SC, there seems to be approval regarding the relevance of this term and the use of technology in cities. This deployment of technology is noted because there is growing pressure to improve the efficiency of cities and reduce negative spill over effects, while promoting aspects related to human capital (Perera *et al.*, 2014; Gil-Garcia *et al.*, 2016). It seems clear that the impact of ICT on better city management is having a transversal impact on all agents (Batty *et al.*, 2012); however, there is a set of "soft" factors, such as citizen participation, collaboration and reward, that are associated with the objectives of managing resources better, improving services offered and encouraging innovation, and all of these factors result in an improvement of wellbeing (Cooray *et al.*, 2017; Zanella *et al.*, 2014). In this way, SCs are moving forward from phase 1.0 (ecosystem connectivity) to phase 2.0 by intensifying the decision-making process through the involvement of all actors (government, corporations and residents) that have a role in it, with the aim of improving quality of life, increasing competitiveness, promoting sustainability and creating open and inclusive platforms (Ottawa, 2017; Eggers *et al.*, 2018; Malone *et al.*, 2009).

Despite the expansion of technology in society, it is worth wondering if the development of the SC is a sustainable pattern. The answer is directly related to the existence of a delicate balance between the concept of a citizen's standard of living, understood as an acceptable minimum level of wellbeing, and the set of distortions that maintaining this level causes in the form of negative spill over effects. Formulas for maintaining this sustainable balance involve great concepts, such as citizen education, corporate initiatives, government intervention, stakeholder involvement, finances and their potential to solve negative spill overs (Ashford *et al.*, 2011).

The consequences of reaching a citizen's standard of living are varied. One of them has its origin in the failures of the market and of policies that determine the prices of products and services in SCs without incorporating the spill over effects that the consumption of these products and services have on sustainability. They are in these urban spaces or in their peripheries where most of the said products and services are generated, exchanged or consumed and where the negative externalities that these consumptions imply take place. Therefore, to achieve a balance between the citizen's standard of living and the consequences of maintaining that standard, it is necessary to minimize these market failures by incorporating new approaches in urban management that consider the most negative consequences of decisions on the sustainability of the urban ecosystem (negative spill overs) and that reward those decisions that benefit sustainability (positive spill overs).

Technology and digitalization are playing a decisive role in alleviating these failures and increasing urban sustainability. This impact can be accelerated if the utilization of technology is combined with other key factors, such as those related to urban political decision-making aimed at sustainability, with measures that reinforce citizens' behaviour and the activism of corporations towards a sustainable strategy, among others. This is when technology achieves its maximum potential as a true integrator vehicle for connecting of all these vectors (institutions, citizens and corporations) in the same direction more agilely and efficiently. This new combination of technology and key factors seeks to alleviate or solve the different unsustainable facets that occur in an SC, with one of these facets being the municipal recycling issue.

The first objective of this paper is to highlight the importance of the digital and programmable economy (PE) as a tool, an integrator, and an efficient vehicle for managing externalities when sustainability like recycling is managed as a value that can be captured and exchanged in a trusted environment. This concept opens up new SC management possibilities and is becoming a key element in formulating tomorrow's SC sustainable strategies, more so if one considers the vertiginous acceleration of negative spill over that occurs in them, for instance, household waste recycling.

The second objective of this paper is to emphasize the need to focus on the treatment of current and new threats to SCs from a more holistic and inclusive point of view, considering the vital importance of the role that institutions, citizens and corporations will play in the search for new sustainability solutions. To face the great challenges ahead, the SC of the future will need to reinforce and promote the active participation of the citizen and of corporations by using the aforementioned opportunity offered by ICT in its different aspects.

To elucidate this subject, an exploratory approach to urban recycling is proposed using the Environment-Social-Economy (ESE) framework and fuzzy logic to present a new waste recycling model that uses an inference algorithm that makes it possible to simulate the level of expected municipal recycling in a city based on the combination of the aggregate factors that are developed in this study. These aggregate factors include the city recycling policy, citizens' recycling reinforcement, corporate sustainability activism and the digital economy. The goal is to find a balance between these inputs in such a way that the municipal recycling rate can be increased by deploying the PE as a backbone.

This paper is organized as follows. In section 2, the theoretical background is described. In section 3, the methodology is presented, followed by the results. Finally, section 4 summarizes the most important conclusions of this paper.

6.2. Theoretical Background

6.2.1. Sustainability and Environmental Policy

The relationship between industrialization and its effects on the environment has captured the attention of economies and organizations throughout recent history. However, all the measures applied by the various online actors to alleviate these effects have been more reactive than proactive. It was not until the recent financial crisis of 2008 that it is tried to offer another approach to alleviating these effects by balancing the various solutions, while considering the effects derived from resolving the crisis at any price.

Historically, in searching for solutions, side effects that increasing production and consumption create for the environment have been underestimated (Ashford *et al*., 2011). In other words, the economy and its agents have been living in a production and consumption bubble (Stiglitz, 2010), without considering the negative spill over effects that this "modus vivendi" generates in the ecosystem. SCs are no strangers to this bubble, and it is necessary to take measures to contain and reduce it by incorporating solutions to the problems that result from the most sustainable SC strategies, bearing in mind that there are many disciplines that include development, globalization and economy or social justice. The concept of sustainability should include other interdisciplinary vectors, such as technological, organizational, institutional and innovation, and its treatment requires both top-down approaches through the intervention from governments with large-scale actions and bottom-up measures through intervention from society with smaller-scale, but more effective, actions (Ashford *et al*., 2011). The problem of sustainability is the result of individual and collective human behaviour; therefore, this problem cannot be exclusively treated as an economic or technological problem without considering the set of mechanisms that intervene in these behaviours (Schmuck et at., 2003).

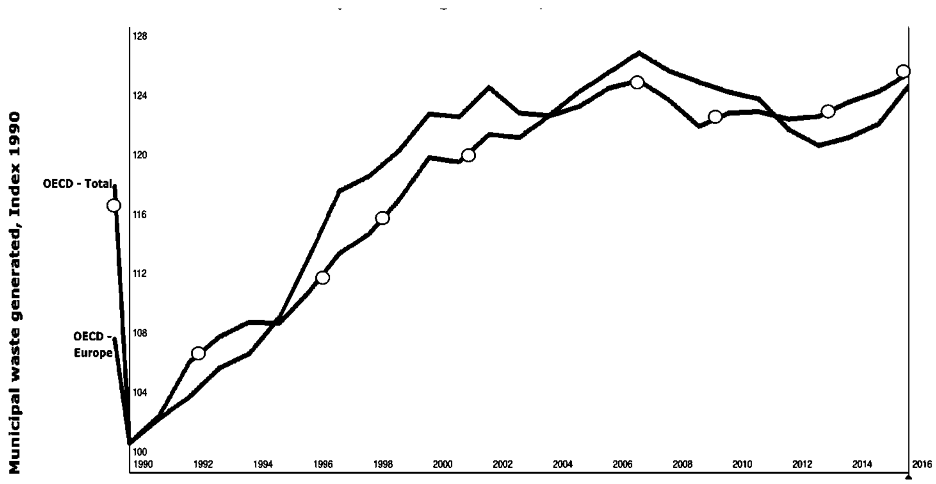
Addressing the sustainability problem from the SC point of view, although cities are generators of positive externalities in that they have played a key role in the development of humanity throughout history as centres for the exchange of information and collaboration, they are also generators of abundant negative externalities such as urban congestion, pollution and the associated environmental impacts (Fernández *et al*., 2015) because of cities' consumption of 2/3 of the world's energy. In addition, cities are responsible for 70% of greenhouse gas emissions (World Economic Forum, 2015) and are generators of 12% of total global waste - the large volume of waste is generated in the so-called primary waste produced by various sectors of economic activity (agriculture, mining, quarrying, manufacturing, energy production, water purification and distribution, and construction) - 77% of this waste originates in households (OECD, 2018). Thus, there is no doubt that the importance of SC in the generation of negative spill overs is enormous. Following the trend, given that 55% of the world's population currently live in urban areas, the forecast for 2050 suggests that this percentage will reach 68% (The World Bank, 2018) and that all these negatives spill overs will only increase.

In the conceptualization of an SC, the vision of sustainability is also included as an important aspect of its development (Caragliu *et al*., 2011); the term "smart environment" has even been coined as a necessary ingredient of an SC (Lee *et al*., 2014). The concept of a sustainable city should be understood as a nonstop process in which the exploitation of resources, investments, technological development and institutional initiatives are consistent with the current and future needs of citizens (World Commission on Environment and Development, 1987). However, a true SC needs to accurately analyse this idea of present and future needs. These needs should be linked closely to the premise that it is the administrations themselves that have the responsibility to envision that future and establish what the tolerable limits for their city are. This responsibility implies the reformulation of sustainability in terms of knowing its effects on the ecosystem at a global level and not only in a particular way and with a long-term time horizon that goes beyond only satisfying the interests of current citizens. In other words, an SC needs to determine the levels of support or the tipping point (points beyond which it is extremely difficult if not impossible to reverse the current trend of a city, regarding such issues as climate change and its effects on health) to which it is subject, so that it does not overshoot points or create situations in which the limits of the system are inadvertently exceeded and that are practically impossible to reverse (Meadow *et al*., 2004).

The term “sustainability” establishes the need for a balance between aspects related to economy, citizenship and the environment in an SC (Ahvenniemi *et al*., 2017). Putting a particular focus on the environment, a smart and sustainable city has goals, such as addressing climate change and environmental issues, to be achieved in an adaptable, reliable, scalable, accessible and resilient way by providing an effective regulatory and local governance mechanism that ensures equitable policies that include the four attributes of the smart and sustainable city: sustainability, quality of life, urban aspects, and intelligence (Dhingra *et al*., 2016). Alternatively, some scholars have developed a similar concept, the smart-eco city, which proposes that the city should be ecologically healthy (by using advanced technologies and having economically productive and environmentally efficient industries), have a responsible and harmonious systematic culture and have a functionally living landscape (Lee *et al*., 2014).

To carry out this sustainable development, developing and developed countries and cities try to find new formulas for managing their negative externalities. For example, it is known that waste generation is closely related to population and urbanization, and there is a correlation between waste generation and GDP per capita or per capita energy consumption (Bogner *et al*., 2008). Therefore, in most developed and developing countries, because of increasing population, prosperity and urbanization, it remains a major challenge for municipalities to collect, recycle, treat and dispose of increasing quantities of solid waste. For example, it can see in Figure 6.1 that since 1990 (base 100), OECD municipal waste has continued to increase; the chart shows a stagnation that coincides with the recent crisis from 2008 to 2012, again registering an increase from 2013 (OECD, 2018).

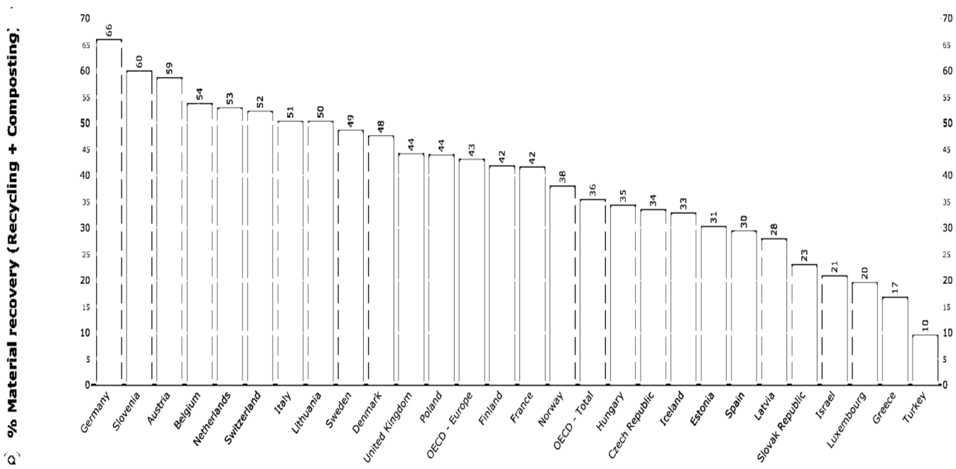
Figure 6.1 Municipal Waste Generated Index from 1990 to 2016, OECD



Source: The author

In relation to waste generated, the United Nations draws attention to the basic concept of waste hierarchy. This concept has undergone several transformations, although it has always emphasized the set of strategies developed by countries and cities to minimize the amount of waste generated (United Nations, 1997), as represented by an ordered pyramid. The basic premise is to avoid and reduce the generation of garbage by applying the 3R concept. The 3Rs (reduce, reuse, recycle) are meant to be a hierarchy, in ascending order of importance (United Nations, 2018). The aim of the waste hierarchy is to extract the maximum practical benefits from products and to generate the minimum amount of waste. The impression of minimizing waste in terms of extent or environmental effects, by reducing the quantity of waste, reusing waste products with simple treatments and recycling waste by using it to produce products is usually referred to as the "3Rs". Again, to put this into context, Figure 6.2 shows the behaviour of OECD countries regarding municipal waste recovery and recycling for the year 2016 (OECD, 2018).

Figure 6.2 % Municipal Waste Recovery



Source: The author

As seen in Figure 6.2, although governments and local administrations have tightened policies towards greater sustainability by promoting the measures included in the 3Rs in the cities, the average percentage of municipal recycling for OECD countries is a scant 36%. Therefore, the situation is far from satisfactory, since more than half of the waste generated in households is still outside of one of the key vectors of the 3Rs established by the United Nations, and there are great opportunities to improve the levels of the reusing and recycling of materials discarded by households.

6.2.2. Sustainable by Citizen Reinforcement and Corporate Brand Activism

Apart from the municipal sustainability policies there are two big key players in the effort to improve SC daily base sustainability: citizens (consumers) and corporations. Focusing on human behaviour, learning theory (Skinner, 1953) and human reinforcement theory refer to the idea that stimuli can be used to produce desired behaviours. B.F. Skinner argues that the administrator only needs to understand the relationship between behaviours and their consequences to create conditions that encourage desirable behaviours and discourage undesirable ones. This appreciation could be used in recycling by city management to motivate citizens and corporations to support good recycling conduct and dissuade bad recycling conduct through positive incentives.

Several approaches have been made to promote recycling and prevent garbage generation (Harder *et al*., 2007; Shaw *et al*., 2008). The use of incentives in the form of reward or recognition to influence recycling differs depending on the type of reward, the target group in question and the value of the reward (Bell *et al*., 2013). Thus, attitudes towards recycling vary according to whether individuals are recyclers or non-recyclers; low-medium recyclers perceive rewards more favourably than existing recyclers (Brook, 2015). Furthermore, studies have revealed that the use of incentives to encourage recycling requires strong advertising campaigns that include a guide to recycling by local councils , public services announcements, and feedback cards (Bell *et al*., 2013). Additionally, these types of initiatives require good planning and a well-developed and an interconnected waste infrastructure to be successful (Fogarty *et al*., 2008).

Currently, corporations, to alleviate the growing problems of sustainability, are undergoing a transformation from engaging in cause marketing (corporate social responsibility) to engaging in brand activism (seeking to have an impact on the biggest societal problems) because the measures taken by governments and online institutions to reverse unsustainability are insufficient and because consumers demand greater involvement by corporations (Kotler *et al*., 2018). The definition of the term “brand activism” is presented by Kotler and Sarkar and includes the set of efforts made by corporations online to promote, impede or direct social, political, economic and environmental reform with the desire to promote improvements in society (Kotler *et al*., 2018).

As society becomes aware of the environmental impact of the products and services it consumes, consumers and citizens are taking responsibility for their purchases and lifestyles. This tendency should be considered by companies to understand to what extent these behaviours affect their brands and the profiles of their consumers, reinforcing the sustainability attributes of their products (Barnes, 2018). Consumers increasingly expect not only the company but also the whole supply chain to be sustainable (Belz *et al*., 2009), and this constitutes a good opportunity for companies. Since transparency and authenticity are key in the digital age, corporations need to increase their sustainability responsibility, ensuring sustainability throughout their value chain from start to finish, including the consumer packaging journey and the household waste materials (recycling and reuse) with which they pack their products. This is a good example of how corporations operate responsibly.

According to Sheffi (Sheffi, 2018), there are four reasons that companies should embrace sustainability: 1) consumers and investors consider it important, and doing nothing could imply losing value; 2) in some cases, it can reduce costs (for example energy costs); 3) reasons of the cultural change type where younger people are more aware of the aspects of sustainability, 4) the potential problems that will be caused by the reduction of the resources available to companies because of global warming. Recent studies confirm that consumers increasingly demand more sustainability in the products they buy, with millennials, Generation Z and Generation X demonstrating more support for sustainability, and corporations are increasingly reaching agreements with manufacturing industries and governments online to reduce waste (Nielsen, 2018). Thus, corporations should be increasingly proactive to make a better world because consumers expect their brands, which are increasingly authentic, thereby establishing a strong line of trust, to contribute to solving the major problems facing the planet. Corporations that implement a progressive policy of brand activism will also experience a significant impact on their sales (Kotler *et al*., 2018). Therefore, corporations can play a big sustainability role in the focus of SCs on daily base citizen routines. Corporations provide products and services to the citizens living in SCs, and corporate involvement in sustainable SCs should be proactive, embracing the entire value chain that their goods or services produce, including negative spill over effects, such as packaging recycling.

In addition, the sustainability as a value and as a source of competitiveness for companies and organizations, is having substantial increase in the academic and business fields such as marketing, financial, management, economics, innovation, technology, or social corporate responsibility and so on, and is shared by many individuals, organizations and institutions who demonstrate the importance of this value including it in their present and future strategic plans (Elkington, 2004; United Kingdom Green Building Council, 2018; Belz *et al*., 2009; Kotler *et al*., 2018).

The conjunction of these measures, the sustainable corporation brand activism together with citizens' recycling reinforcement and institutional recycling policy, can decisively contribute to increasing the level of municipal recycling in the cities. However, these measures should find a facilitator and integrator route that unites endpoints; this is the technological vector. Currently, ICT measures, in some way, are contributing greatly to municipal waste management and increasing municipal recycling. However, considering institutional policy, citizen habits and proactive corporate activism as a basis, these ICT measures are not sufficient alone. In searching for a better resource combination, municipal recycling solution could be accelerated through better endpoints management by digital technology and PE as a backbone connecting citizens, corporations and institutions.

6.2.3. Programmable Economy as an Integrator Backbone

There are two interesting approaches to the role of technology in economics and sustainability. One is anchored in the concept of substitutability (Solow, 1993) and the other in the idea of the steady-state economy (SSE) (Czech *et al*., 2004). Solow's idea of sustainability is founded on the fact that technology can create high degrees of substitutability between one resource and another and implicitly indicates that nature and human-made capital are somehow fungible, arguing that essentially any kind of natural capital can be replaced by the hand of man. What is telling is that if resources are fungible, society has no obligation to protect those resources for future generations, and society is obliged to leave only the ability to create wellbeing without having to take resources into account. In contrast, Daly defends the idea that many of the resources that nature provides cannot be replaced by products or services made by human beings, arguing the first principle of thermodynamics, which is included in the SSE model, whose objective is to keep the throughput of a raw material (low entropy) and waste (high entropy) at levels within the regenerative and assimilative capacity of the ecosystem. Therefore, the neoclassical economic view sees growth as a continuous expansion, while the SSE model believes that the economy must be in permanent equilibrium with the ecosystem in which it operates (Ashford *et al*., 2011). Regarding these two approaches, it is important to say that the revolution of ICT technologies have the capacity to facilitate sustainable innovations by reducing the amount of materials and energy needed while stimulating the economy so that sustainability becomes a "chosen direction" by the agents; therefore, sustainability should not be considered as posing a dilemma between growth and sustainability itself but rather as an opportunity that needs to be considered (Pérez, 2016). Tomorrow's SCs requires facing this dilemma, regarding whether the natural goods that affect an SC in a broad sense can be substituted with goods made by the human hand through technology or if said technology can become a complement to promote the balance of the ecosystem.

Keeping the need to maintain the balance of the ecosystem included in SSE strongly in mind, it wants to argue how the PE can contribute to improving this balance in the SC ecosystem by reducing the entropy that negative externalities generate, for example, a low rate of municipal recycling, increasing the connection and integration of the endpoint (institutions, corporations and citizens) that operate in them. However, in what way can SCs combine technological advances with citizen reinforcement, corporate activism and institutional policy to increase the municipal recycling rate efficiently, rapidly and transparently? The PE will be the answer.

The PE concept was introduced by Gartner in 2014 to refer to an intelligent economic system that supports and manages the production and consumption of goods and services, making possible new exchanges of value (monetary and nonmonetary) (Gartner, 2015). The PE is supported through blockchain or Distributed Ledger Technology (DLT), Internet of Things (IoT), monetization, a token economy, smart contracts, artificial intelligence and cryptography, thereby supporting new forms of value exchange, new types of markets and new forms of the economy. In this PE, it will be the individuals and the smart machines that will define value and determine how exchanges will be determined through peer-to-peer transactions involving organizations and even smart machines and agents (Gartner, 2015).

The PE permits the creation of new business models by combining the physical world with the digital one, allowing predictions regarding behaviour to be made while changing the ways in which value is exchanged. The PE's implications include removing the middleman, imagining new ways of exchanging the value of the tangible and intangible between people and institutions, rethinking new forms of governance relationships, allowing greater automation by minimizing external oversight and decentralizing the economy, and managing information better. However, perhaps one of the greatest characteristics of the PE is the possibility of monetizing things and services by redefining the economy and the way in which value is exchanged between intelligent physical or intangible things between several actors, including corporations, citizens, and institutions (Sloan, 2018), enabled by the second generation of the internet, Web 2.0. The transformation of the web from an "Internet of information" to an "Internet of value" radically changed the operation of the economy and of institutions (Tapscott, 2017).

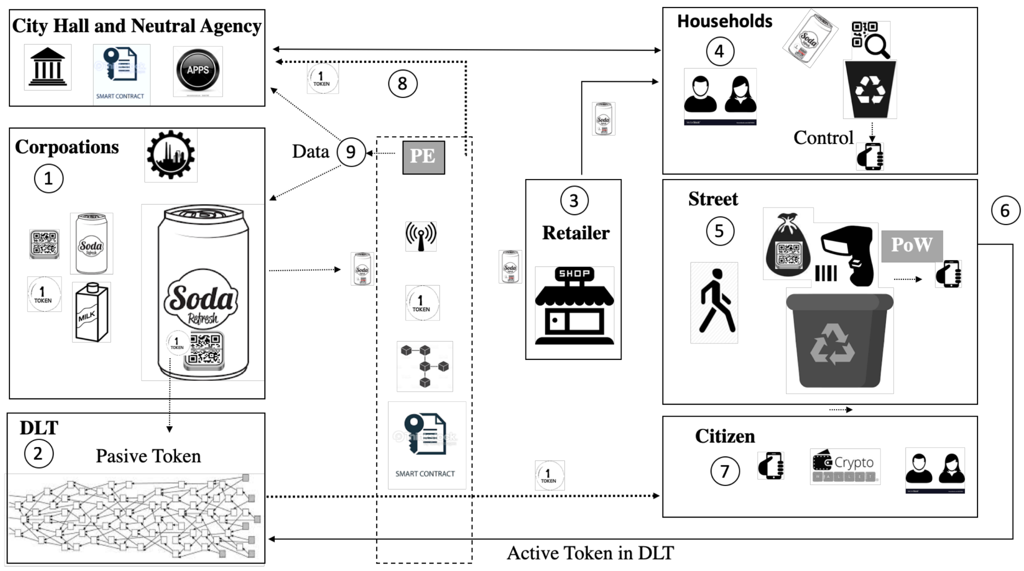
PE technology drastically reduces the cost of trust, allows to imagine new business models and opens the possibility of deploying new forms of collaboration as a source of trust, PE can expand corporations', institutions' and citizens' degree of DT, whereby processes and objectives can be shared among all actors. All this is possible because this technology makes the information contained within it immutable, safe, shared and consensual (Harvard Business Review, 2017).

On the other side, a PE by smart contracts or intelligent contracts, a concept attributed to Nick Szabo in 1996 (Szabo, 1996), facilitates the agreement of individuals, organizations and institutions in such contracts over how they want their business or public services to be carried out consistently and automatically, keeping participant interactions recorded transparently at all times. This technology allows better decision-making between people and between machines without human intervention.

In addition, one of the most important characteristics of PE technology is that it allows the reduction, very consistently, of the so-called "transaction costs" defined in Coase's work, "The Nature of the Firm" (Coase, 1937). These costs include the cost of organization, negotiation, information monitoring and coordination (Potts *et al*., 2017); digital technologies can clearly reduce many of these costs. PE technology tends to reduce decisions and many coordination functions could be replaced by software, opening new institutional and corporation possibilities to reduce transactions, control, and monitoring costs and to provide the possibility of achieving more efficient data coordination.

Thus, PE allows a strong boost to municipal recycling by using IoT, DLT, smart contracts, tokens and digital wallets. If increasing the household recycling rate is desired, governments, by having a sustainable policy focus, can force corporations to monetize the potentially recyclable materials that they use in their products. Thus, they can add value to their token packs by incorporating virtually passive tokens in them. These pack tokens can be active after the human household recycling operation so that when citizens recycle their household bag into street recycling containers, a proof of work (PoW) is produced, and these tokens are activated, converting the potential intrinsic value of the recycled packaging into real value that is automatically transferred to the active subject's (citizen) wallet. The entire process can be produced in a decentralized way by the PE's supporting various elements, such as the blockchain or DLT, the wallets, and the signing of smart contracts between citizens, corporations and the administration, as shown in Figure 6.3:

Figure 6.3 Waste Recycling Proof of Work (PoW)



Source: The author

In other words, the mechanism would be composed of the following steps. Step 1: Corporations, to increase municipal recycling, can integrate a passive recycling token into their packs in their production process. Step 2: This token is automatically registered in the DLT remaining in passive mode or stand by. Step 3: Product arrives at the retailer making the sale as usual. Step 4: Consumers in their home after the act of consumption, deposit the empty package in the household recycling container, previously scanning it in such a way that the deposit of the various recycled packaging is accumulated in their household container scan. Step 5: Once the household packaging is accumulated, the citizen deposits the bag of packaging to be recycled through the recycled packaging bag, in the street special recycling container (paper, glass, plastic), which contains a summary of all packaging by type that consumers have recycled separately. Here, the Proof of Work (PoW) is produced, converting the passive tokens to active tokens by transferring individualized package passive tokens in active tokens through the citizen wallet through the PE (steps 6 and 7). Step 8: Local house hall (or independent administrator) receives a fraction of each activated token to deal with the necessary infrastructures required by the total system. Step 9: Finally, corporations and municipalities receive aggregate information on recycled products through street containers, maintaining citizens' privacy at all times. These data become the core. In this process, corporations advance the economic value of the final data that they will obtain by recovering the cost in the form of aggregate consumer information while maintaining the households' privacy. This information can be very valuable to corporations because it constitutes a reliable proof of work of recycling and household consumption, allowing them to direct promotion activity towards selling and recycling. After that, citizen token income can be exchanged for public transportation discounts, payment of local taxes, or sustainable commerce coupons, or users can exchange the income for fiat money with minimal human interaction. Additionally, city hall income can be reinvested directly in maintaining and constructing new city infrastructure.

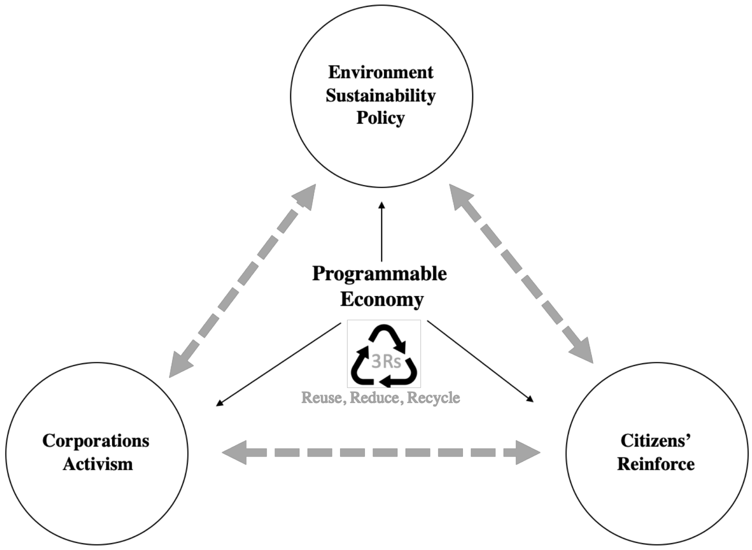
Therefore, PE by spill-over effects' monetization when sustainability such as recycling, is managed as a value by the agents (Elkington, 2004; United Kingdom Green Building Council, 2018), enables the possibility of deploying the digital asset concept (a digital asset market representing physical assets, such as recycle packages in cities). In other words, through

PE technologies, it is possible to create a new city household recycling strategy that motivates citizens through positive incentives and motivates corporations in recycling brand activism by allowing them to exchange tokens for data. Additionally, the PE, as applied to institutional administration, becomes an excellent technology for governance, decentralization and information systems. All of the above can have an impact on productivity and organizations' efficiency and will be extremely beneficial for organizations (Davidson *et al*., 2018).

In view of the above explanation and to put all the concepts in order (sustainability policy, citizen reinforcement, and corporation activism), a new approach to urban recycling is presented using the environment-social-economy (ESE) framework formulated by Ashford and Hall (Ashford *et al*., 2011). This triangle of sustainability is frequently represented by the economy, the environment and social concerns and explains that all policies that affect the economy and the environment have social impacts. In addition, long-run flows of environmental services are provided at a level sufficient to maintain a stable ecosystem.

Taking the ESE model as reference, it is proposed that the solutions to the municipal recycling problem become more holistic and include, in addition to the different functions of Batty's Smart City (Batty *et al*., 2012), the combination of the aspect of the economy related to corporate activism; the environment policy factors encouraged by institutions; and the aspects related to citizens' behaviour, such as human reinforcement, with the technological factors generated by digitalization and the PE. All of this is contemplated in the Environment-Corporations-Citizens-Programmable Economy Model (ECOCIPEM). ECOCIPEM is modelled as a digital ecosystem, a set of functional niches and roles, a set of elements located within a complex whole in which each niche fulfils a particular function sharing standardized digital platforms (Rynn, 2007; Gartner, 2017) and the PE deployment as it is shown in Figure 6.4, in order to improve municipal recycling.

Figure 6.4 ECOCIPEM Model



Source: The author

The problem that is to be solved revolves around knowing to what extent the modification of the recycling factor by citizens' incentives, city policy and corporate recycling activism strategy combined through PE technology increases the municipal recycling rate. Specifically, and as a first phase, it is necessary to know whether the implementation of recycling incentives, a city recycling policy focus and corporate recycling activism, all integrated by the PE, as described in Figure 6.4, can alter municipal recycling rates (3Rs) more than the implementation of citizen incentives and corporate activism without a PE to maintain a city policy fix.

In the search for such results, there are no simple solutions, since inaccuracy and uncertainty exist within cities. In addition, certain parts of the proposed municipal recycling system are unknown and cannot be measured reliably without clear limits on the concepts of sustainability policy, corporate activism and citizen behaviour. For this reason, making use of fuzzy systems methodology to reproduce reality more faithfully and to relax restrictions is proposed because there are concepts that have no clear limits. Therefore, fuzzy science is used to find an algorithm for understanding what the better way would be to deploy the ECOCIPEM.

6.3. Methodology

6.3.1. Fuzzy Sets

The theory of fuzzy sets was introduced in 1965 by Lofti A. Zadeh. The idea resides in the fact that the elements that make up human thought are not numbers but linguistic labels. According to the principle of incompatibility as the complexity of a system increases, the ability to be precise decreases to the point that precision and meaning are exclusive characteristics (Zadeh, 1975). From this idea, fuzzy logic allows to represent common thought in a mathematical language based on the theory of fuzzy sets and their characteristic functions. Fuzzy logic's applications have increased to the point of being considered a real revolution, developing a large number of extensions, such as soft computing that covers the fuzzy sets and fuzzy logic for approximate reasoning and the theory of possibility (Merigó-Lindahl, 2009).

According to this theory, it is been considering a referential set or universe of discourse, U, and an ordinary subset, $A \subset U$, of those elements that fulfil a specific characteristic. For ordinary subsets there are only 2 possibilities, $\forall x \in U$: "x" satisfies the characteristic *($x \in A$)* or "x" does not comply ($x \notin A$). Therefore, the membership function of A is defined:

$$\forall\ x \in U\ \mu_A(x) = \begin{cases} 1\ if\ x\ \in A \\ 0\ if\ x\ \notin A \end{cases}$$

An ordinary subset of $A \subset U$ is symbolized by the pair *(U, $\mu_A(x)$)*.

Now, if the elements of A can take any value in a range [0, 1], it could be said that there are elements of U that fulfil the characteristics defined in subset A, but only to a certain degree. In this sense, the membership function of A will be defined as,

$$\forall\ x \in U:$$
$$\mu_A(x): U \rightarrow [0,1]$$
$$X \rightarrow \mu_A(x) = \alpha \in [0,1]$$

In this way it is possible to construct a fuzzy subset (U, $\mu_A(x)$) symbolized by $A \subset U$.

$$A = \{(x, \mu_A(x)) \,/\, x \in U\}$$

On the other hand, fuzzy logic allows the assignment of linguistic values to the variables of a problem, similar to the evaluation of a parameter usually conducted by people, whether they are experts or not (Zimmermann, 1987; Jones, 1994).

In this sense, the universe of discourse is the range of possible values for an input to a fuzzy system. A fuzzy set is any set that allows its members to have different grades of membership (membership function) in the interval [0,1]. Linguistic variables are the input or output variables of the system whose values are words or sentences from a natural language, instead of numerical values. A linguistic variable is generally decomposed into a set of linguistic terms.

6.3.2. Mamdani Fuzzy Inference Systems

There are two well-known rule-based Fuzzy Inference Systems (FIS), the Mandami fuzzy method (Mandami *et al.*, 1975) and the Tagaki Sugeno (T-S) fuzzy method (Takagi *et al.*, 1985). The main idea of the Mandami method is to describe process states by means of linguistic variables and to use these variables as inputs to control rules. The Mandami fuzzy model involves developing membership functions and defining the subsequent rules. The rules connect the input variables with the output variables and are based on the fuzzy state description that is obtained by the definition of the linguistic variables.

The basic components of a Mandami Fuzzy System (Mandami, 1997) are the following: fuzzification, a knowledge base with an inference system and defuzzification. Meanwhile, the general structure of a fuzzy model includes the input variables, the development of rules and the output variables.

i. Fuzzification, understood as the introduction of input values and their interpretation as linguistic values, determines the membership functions of the system variables in the fuzzy sets. The universe of discourse of each variable was determined by the linguistic components for input and for output. A fuzzy set is defined by the expression below:

$$A = \{(x, \mu_A(x)) \, / \, x \in U, \mu_A(x) \in [0,1]\}.$$

where U represents the universal set, x is an element of U, A is a fuzzy subset in U and $\mu_A(x)$ is the membership function of fuzzy set A.

ii. The knowledge base consists of fuzzy rules defined with the help of experts. A single fuzzy if-then rule assumes the form:

If x is A Then y is B

where A and B are linguistic values defined by fuzzy sets in the range (universe of discourse) x and y, respectively. The "x is A" part of the if-then rule is called the antecedent or premise, while the "y is B" part of the rule is called the consequent or conclusion (Yuanyuan *et al.*, 2009). During data processing, a fuzzy system fuzzifies the crisp data and applies the Mandami inference system using the fuzzy rules (by experts). In this study, the fuzzy control rules are of the form

$$R_i: If\ X_1\ is\ A_i^1\ and\ \dots\ and\ X_r\ is\ A_i^r\ Then\ Y\ is\ C_i$$

where the variables $X_j, j \in \{1,2, \dots, r\}$, and *Y* have the domains U_j and V_j, respectively. The firing levels of the rules, denoted by $\{\propto_i\}$ are computed by

$$\propto_i = T\ (\propto_i^1, \dots, \propto_i^r)$$

where T is a t-norm and $\propto_i^j$ is the firing level for $A_i^j, j \in \{1,2, \dots, r\}$. The causal link from $X_1, \dots, X_r$ to Y is represented using an implication operator, *I*. This results in the conclusion C'_i inferred from the rule R_i being

$$\mu_{C'_i}(x) = I\left(\alpha_i, \mu_{C_i}(x)\right), \forall x \in U.$$

and using Mandami implication *I* the formula is

$$\mu_{C'_i}(x) = I_M(\alpha_i, \mu_C(x)) = \min\{\alpha, \mu_C(x)\}.$$

The final output of the model is the aggregation of outputs from all rules using the max operator:

$$\mu_{C'}(x) = \vee_{i=1}^{n} \left[\alpha_i \wedge \mu_{C_i}(x)\right] = \vee_{i=1}^{n} \mu_{C'_i}(x).$$

iii. Defuzzification is used to obtain an output from the previous fuzzy set. A centroid method is usually used. Subsequent defuzzification produces a crisp value output. Defuzzification uses some methods, such as center of gravity or centroid (COG), mean of maximum (MOM), and first of maximum (FOM). Centre of gravity is the most popular and the most precise method used for defuzzification. The center of gravity method is a grade weighted by the areas under the aggregated output functions. The formula for the centroid is given as

$$\text{COG} = \frac{\int \mu_c(x) x dx}{\int \mu_c(x) dx}$$

where $\int \mu_c(x)dx \neq 0$ $for\ all\ \mu_i$.

6.3.3. Fuzzy Inference System to Estimate Municipal Recycling

This section introduces a fuzzy inference system to estimate municipal recycling (FISMUR) by algorithm. The objective of the proposed algorithm is to provide the municipal recycling rate based on the input given as recycling policy focus (relationship between country environment sustainability policy and municipal recycling rate), recycling oriented (corporations recycling activism and positives incentives for citizens' recycling) and a technological factor (programmable economy). The linguistics variables, fuzzy set and universe of discourse are given in Table 6.1 and Table 6.2:

Table 6.1 Linguistic Variables

Recycling Policy Focus (RPF)	Recycling Oriented (RO)	Programmable Economy (PE)	Municipal Recycling (MR)	Municipal Recycling actual (MRa)
-Actual Municipal Recycling/ Environmental Sustainability Policy Index.	-Customer waste recycling incentives. -Corporations recycling activism.	-Programmable economy (IoT, blockchain, DLT, smart contracts, monetization and token economy).	-%Material recovery (recycling + composting).	-%Material recovery (recycling + composting) actual.

Source: The author

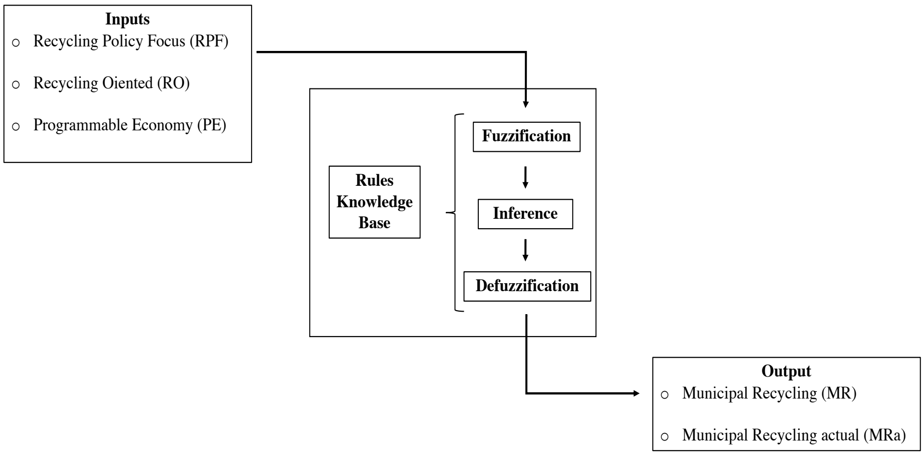
Table 6.2 Fuzzy Set and Universe of Discourse

Linguistic Variable	Fuzzy Set	Universe of Discourse
-Recycling policy focus (RPF)	$A_{RF} = \{x, \mu_s(x) \ / \ x\epsilon[0,100]\}$	$U = [0,100]$
-Recycling oriented (RO)	$A_{RO} = \{x, \mu_C(x) \ / \ x\epsilon[0,100]\}$	$U = [0,100]$
-Programmable economy (PE)	$A_{PE} = \{x, \mu_E(x) \ / \ x\epsilon[0,100]\}$	$U = [0,100]$
-Municipal recycling (MR)	$A_{MR} = \{x, \mu_T(x) \ / \ x\epsilon[0,100]\}$	$U = [0,100]$
-Municipal recycling actual (MRa)	$A_{MRa} = \{x, \mu_T(x) \ / \ x\epsilon[0,100]\}$	$U = [0,100]$

Source: The author

Figure 6.5 shows a block diagram of the proposed Fuzzy Inference System Municipal Recycling (FISMUR) algorithm which includes a fuzzification block, a knowledgebase, a fuzzy inference engine and a defuzzification block.

Figure 6.5 FISMUR Algorithm



Source: The author

The proposed algorithm consists of three steps: fuzzification, fuzzy rules, and defuzzification.

Step1 – Fuzzification: in order to keep the number of fuzzy rules at a reasonable level, input can be defined as fuzzy set levels with three membership functions known as “Low”, “Medium” and “High”. For the output, the municipal recycling fuzzy set has three membership functions, such as “Low”, “Medium”, and “High”.

To define the recycling policy focus, recycling oriented and PE membership functions, it is used the environmental sustainability index (World Economic Forum, 2018) and municipal recycling index (OECD, 2018), degree of customer orientation index (World Economic Forum, 2018) and digital adoption index (The World Bank, 2018) approach respectively behind a universe of discourse valued between 0 and 100. To obtain the output municipal recycling membership functions, it is used municipal waste generation and treatment (% material recovery recycling + composted) (OECD, 2018) approach as a close reference in a universe of discourse valued between 0 and 100 and for municipal recycling actual situation a universe of discourse valued between 0 to 100. The reason that this indexes are used is that there is a positive correlation between the municipal recycling index by OECD countries with the degree of customer orientation index, the digital adoption index and the environment sustainability index with $R^2 = 0.453, 0.518$ and 0.536 respectively.

It is divided the initial linguistic variables where each has their own appropriated linguistic values defining the fuzzy set membership function, as explained in Tables 6.3, 6.4, 6.5, 6.6 and 6.7.

Table 6.3 Recycling Policy Focus Membership Function (RPF)

Linguistic Variable	Functions
Low (L)	L Function: $1-\mu_x = \begin{cases} 0 & if\ x \leq 20 \\ \frac{x-20}{45-20} & if\ x \in (20,45) \\ 1 & if\ x \geq 45 \end{cases}$
Medium (M)	Triangular Function: $\mu_x = \begin{cases} 0 & if\ x \leq 20 \\ \frac{x-20}{45-20} & if\ x \in (20,45) \\ \frac{70-x}{70-45} & if\ x \in (45,70) \\ 0 & if\ x \geq 70 \end{cases}$
High (H)	L Function: $1-\mu_x = \begin{cases} 0 & if\ x \leq 55 \\ \frac{x-97}{97-55} & if\ x \in (55,97) \\ 1 & if\ x \geq 97 \end{cases}$

Table 6.4 Recycling Oriented Membership Function (RO)

Linguistic Variable	Functions
Low (L)	L Function: $1-\mu_x = \begin{cases} 0 & if\ x \leq 55 \\ \frac{x-55}{70-55} & if\ x \in (55,70) \\ 1 & if\ x \geq 70 \end{cases}$
Medium (M)	Triangular Function: $\mu_x = \begin{cases} 0 & if\ x \leq 65 \\ \frac{x-65}{75-65} & if\ x \in (65,75) \\ \frac{85-x}{85-75} & if\ x \in (75,85) \\ 0 & if\ x \geq 85 \end{cases}$
High (H)	L Function: $1-\mu_x = \begin{cases} 0 & if\ x \leq 80 \\ \frac{x-80}{99-80} & if\ x \in (80,99) \\ 1 & if\ x \geq 99 \end{cases}$

Table 6.5 Programmable Economy Membership Function (PE)

Linguistic Variable	Functions
Low (L)	L Function: $1-\mu_x = \begin{cases} 0 & if\ x \le 15 \\ \frac{x-15}{70-15} & if\ x \in (15,70) \\ 1 & if\ x \ge 70 \end{cases}$
Medium (M)	Triangular Function: $\mu_x = \begin{cases} 0 & if\ x \le 60 \\ \frac{x-60}{70-60} & if\ x \in (60,70) \\ \frac{70-x}{80-70} & if\ x \in (70,80) \\ 0 & if\ x \ge 80 \end{cases}$
High (H)	L Function: $1-\mu_x = \begin{cases} 0 & if\ x \le 75 \\ \frac{x-75}{80-75} & if\ x \in (75,80) \\ 1 & if\ x \ge 80 \end{cases}$

Table 6.6 Municipal Recycling Actual Membership Function (MRactual)

Linguistic Variable	Functions
Low (L)	L Function: $1-\mu_x = \begin{cases} 0 & if\ x \le 5 \\ \frac{x-5}{15-5} & if\ x \in (5,15) \\ 1 & if\ x \ge 15 \end{cases}$
Medium (M)	Triangular Function: $\mu_x = \begin{cases} 0 & if\ x \le 8 \\ \frac{x-8}{24-8} & if\ x \in (8,24) \\ \frac{24-x}{40-24} & if\ x \in (24,40) \\ 0 & if\ x \ge 40 \end{cases}$
High (H)	L Function: $1-\mu_x = \begin{cases} 0 & if\ x \le 32 \\ \frac{x-32}{77-32} & if\ x \in (32,77) \\ 1 & if\ x \ge 77 \end{cases}$

Table 6.7 Municipal Recycling Membership Function (MR)

Linguistic Variable	Functions
Low (L)	L Function: $1-\mu_x = \begin{cases} 0 & if\ x \leq 10 \\ \frac{x-10}{20-10} & if\ x \in (10,20) \\ 1 & if\ x \geq 20 \end{cases}$
Medium (M)	Triangular Function: $\mu_x = \begin{cases} 0 & if\ x \leq 16 \\ \frac{x-16}{36-16} & if\ x \in (16,36) \\ \frac{36-x}{56-36} & if\ x \in (36,56) \\ 0 & if\ x \geq 56 \end{cases}$
High (H)	L Function: $1-\mu_x = \begin{cases} 0 & if\ x \leq 40 \\ \frac{x-40}{96-40} & if\ x \in (40,96) \\ 1 & if\ x \geq 96 \end{cases}$

Source: The author

Step2 – Fuzzy Rules: in this step, it is used linguistic quantification to specify a set of rules that captures the experts' knowledge about how to control the output.

To be able to determine which the rules to apply to the model are, two SC experts (Public Administration and Private Enterprise) were asked through personal interviews to carry out the rules.

It is important to mention that this project has been divided into two phases: In a first phase, it is tested the model with two SC experts to later introduce their acquired learning, then go to phase two and extend the number of experts to 10 in the fields of: institutional, technology, blockchain, management planning, private sector, waste management industry and academics. The interview methodology started by explaining the model, then experts completed some matrix in order to establish the importance of recycling policy focus, citizens' recycling oriented and corporations recycling activism and digital and PE in municipal recycling, thereby establishing the rules given in Table 6.8.

Step3 – Defuzzification: the inputs for the fuzzy system introduced in this study were recycling policy focus, recycling oriented and PE, all of which are crisp. Initially, the fuzzy system fuzzifies the crisp data and then, with the Mandami inference system, applies the fuzzy rules. Finally, using COG, it is determined the municipal recycling (MR and MRactual).

Table 6.8 Rules (Knowledge Base)

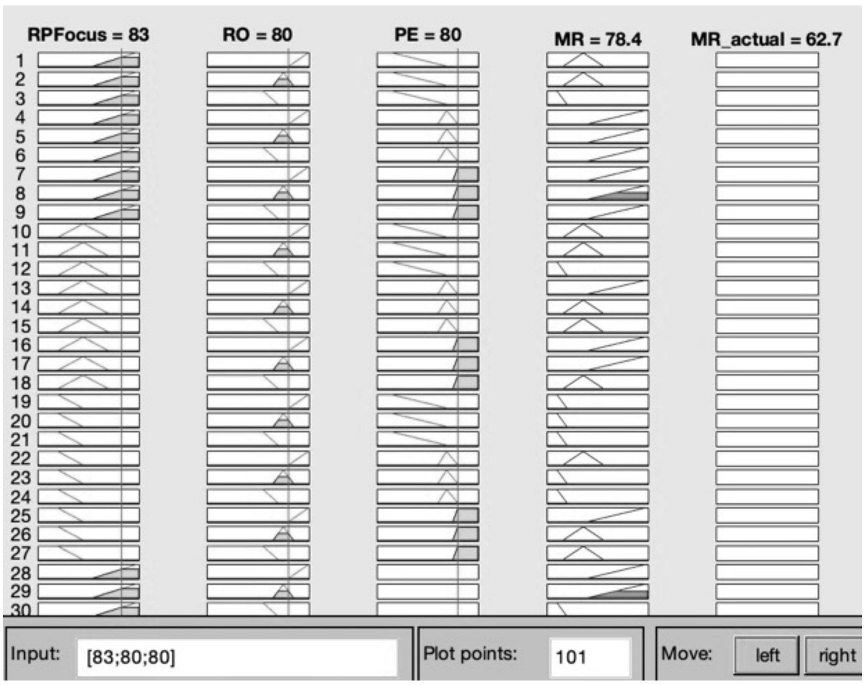
Rule	If RPF	And RO	And PE	Then MR	Then MRactual
1	H	H	L	M	-
2	H	M	L	M	-
3	H	L	L	L	-
4	H	H	M	H	-
5	H	M	M	H	-
6	H	L	M	H	-
7	H	H	H	H	-
8	H	M	H	H	-
9	H	L	H	H	-
10	M	H	L	M	-
11	M	M	L	M	-
12	M	L	L	L	-
13	M	H	M	H	-
14	M	M	M	M	-
15	M	L	M	M	-
16	M	H	H	H	-
17	M	M	H	H	-
18	M	L	H	M	-
19	L	H	L	L	-
20	L	M	L	L	-
21	L	L	L	L	-
22	L	H	M	M	-
23	L	M	M	L	-
24	L	L	M	L	-
25	L	H	H	H	-
26	L	M	H	M	-
27	L	L	H	M	-
28	H	H	None	H	-
29	H	M	None	H	-
30	H	L	None	L	-
31	M	H	None	H	-
32	M	M	None	M	-
33	M	L	None	M	-
34	L	H	None	M	-
35	L	M	None	L	-
36	L	L	None	L	-
37	L	None	None	-	L
38	M	None	None	-	M
39	H	None	None	-	H

Source: The author

6.3.4. Results

Figures 6.6 and 6.7 show the output of the fuzzy inference system in Matlab (Toolbox Fuzzy Logic Matlab) (Matlab, 2018), the software used for predicting municipal recycling. For example, if the values of input variables for a particular country (i.e., recycling policy focus-RPF, recycling-oriented citizen incentives and corporate activism-RO, and the digital and programmable economy-PE) are 83, 80 and 80 on the scale 0-100, respectively, then the membership functions profile is shown in Figure 6.6. The values of output variables municipal recycling (MR), belonging to the high language variable, and actual municipal recycling (MRactual) would be 78.4 and 62.7, respectively, observing better performance in MR simulation than MRactual after RO and PE variables have been used.

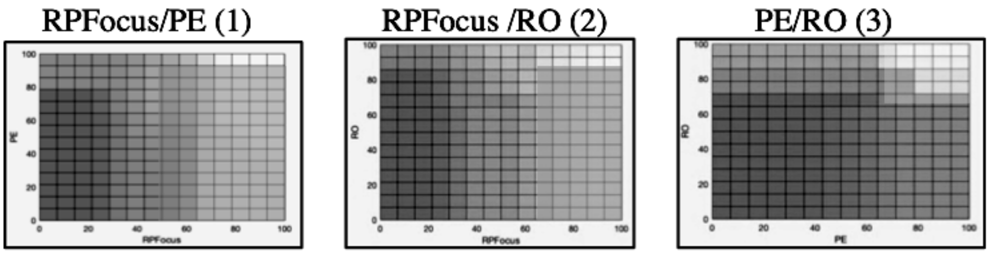
Figure 6.6 Membership Function Example from Matlab



Source: The author

Control levels between input structure variables with IF-THEN are presented in Figure 6.7 (dark, grey and white areas represent low, medium and high municipal recycling, respectively). As shown, municipal recycling increases as the recycling policy focus (horizontal axis) and the PE (vertical axis) increases always from the minimal level of the recycling policy focus variable, its effects being more noticeable if the recycling policy focus is larger (1). Thus, the intensive use of the PE from a certain level of recycling policy focus has a greater impact on the increase in municipal recycling levels. On the other side, actions carried out through initiatives for the recycling oriented, RO (positive citizen incentives and corporate activism), shown on the vertical axis, alone to increase the level of municipal recycling are more limited to certain levels of city recycling policy focus (horizontal axis) (2). In other words, at the same level of recycling policy focus, the expected results are greater if the two inputs (RO plus PE) are combined. Thus, it is clear that the joint effect of the recycling oriented through the deployment of the PE in increasing municipal recycling is greater (3).

Figure 6.7 Control Levels between Inputs and Outputs (Matlab)



Source: The author

Empirical data from the recycling policy focus (RPF) vs predicted values by the fuzzy inference system municipal recycling (FISMUR) simulation in several OECD and non-OECD cities are revealed in Table 6.9 with different levels of inputs.

Table 6.9 Fuzzy Inference System Municipal Recycling (FISMUR)

Country	Recycling Policy Focus RPF actual	% Municipal recycling + composting, 2016, MR	FISMUR(1) RPF=actual RO=0, PE=0 MRactual	FISMUR(2) RPF=actual RO=80 P=0	FISMUR(3) RPF=actual RO=80 PE=80
Germany	89	66	64	65	80
Slovenia	83	60	62	64	78
Austria	73	59	60	60	76
Belgium	83	54	62	64	78
Netherland	73	53	60	60	76
Switzerland	63	52	43	56	65
Italy	79	50	62	62	77
Lithuania	79	50	62	59	77
Sweden	64	49	45	59	65
Denmark	65	48	47	49	66
Luxemburg	60	47	37	59	65
UK	66	44	49	59	68

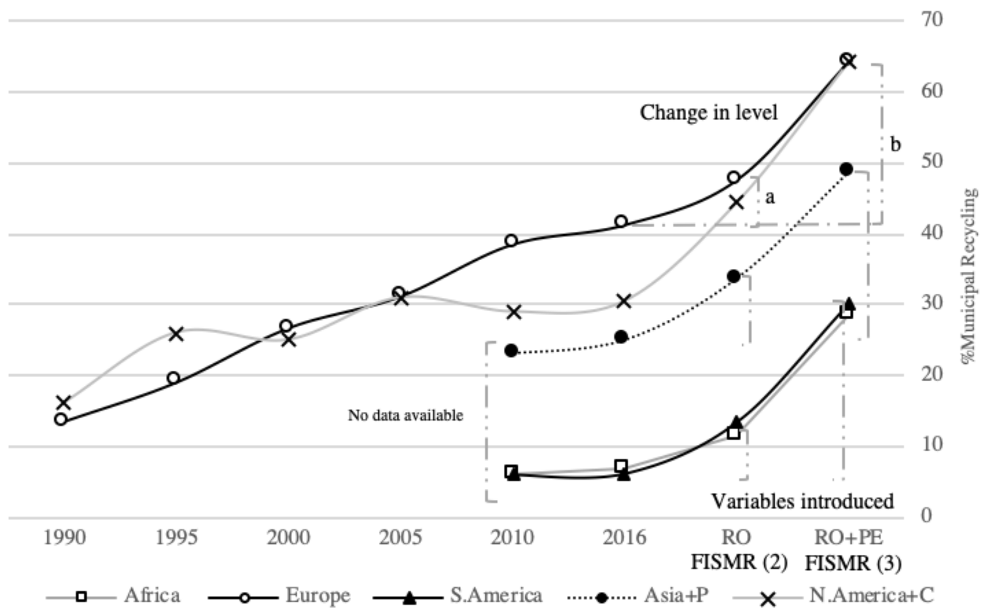
Poland	67	44	52	59	70
Norway	59	43	34	47	65
Finland	59	42	34	47	65
France	62	42	41	54	65
Ireland	61	41	40	51	65
Hungary	58	34	33	44	65
Czech R	48	33	24	36	62
Iceland	48	33	24	36	62
Estonia	44	31	24	36	62
Spain	46	30	24	36	62
Latvia	40	28	24	30	59
Slovak R	34	23	22	30	52
Portugal.	31	19	19	25	49
Greece	27	17	17	22	43
Turkey	19	9	14	8	23
Europe	59	41	40	47.3	64.4
Korea	99	59	64	67	80
Australia	61	42	40	51	65
China	67	30	52	59	70
Japan	34	21	19	30	52
Thailand	22	11	10	13	29
Indonesia	14	6	6	8	23
Philippines	10	5	5	8	23
Asia+P	44	25	28	33.7	48.8
United States	67	35	52	59	70
Canada	40	27	22	30	59
N. America+C	53	31	37	44,5	65.5
Colombia	34	20	19	30	52
Mexico	6	4	5	8	23
Brazil	2	1	5	8	23
Chile	1	0,5	5	8	23
S. America	11	7	8	13,5	30.2
Israel	38	21	21	28	56
Iran	12	6	6	8	23
Egypt	11	6	6	8	23
Niger	8	4	5	8	23
Morocco	7	4	5	8	23
Africa	15	8	8	12	29.6

Source: The author (Scale 0-100)

As seen in Table 6.9, there is a good correlation between the Municipal recycling (2016) and the recycling simulation FISMUR (1), with $R^2 = 0.896$, which is notably high. On the other hand, Figure 6.8 also shows that the greatest potential for municipal recycling was obtained from the variable recycling oriented (RO) and when PE was carried out at the same time - FISMUR (3) - and not oriented recycling in isolation - FISMUR (2) -, keeping the recycling policy focus constant, producing a significant "level change" effect in the variable on municipal recycling, this being greater when the two factors are combined (change in level “b"), that is done only through the recycling oriented (change in level "a") on the trends registered during the last years (1990-2016) for each set of countries.

In spite of that, for developing countries, it is better to improve their recycling policy focus as a priority because although they increase RO and PE variables at the same time or isolated, they cannot achieve more than 30% of municipal recycling rates from 9%, compared with developed countries that have achieved rates of more than 60%. Alternatively, for developing countries, it will be very expensive to obtain high levels of PE and RO (i.e., 80) if they have poor values of them too.

Figure 6.8 % Municipal Recycling Trends by Countries Set (1990-2016, RO, RO+PE introduced)



Source: The author

6.4. Conclusions

The only way to guarantee future cities' survival is to decisively face the challenges of a sustainable SC path by, for example, managing their negative externalities, capitalizing on their extraordinary positive ones and extending their time horizon responsibility. For this, the SC should involve all agents without exception, excluding partial visions and interests, since multidisciplinary points of view are needed to address highly complex problems such as sustainability. Undoubtedly, to accelerate this process, technology will play an increasingly important role, its use being more decision-making intensive by intensifying, integrating, facilitating and connecting SC critical endpoints rather than being only a tech milestone.

As already mentioned, beyond the different theories about the role of technology in sustainability strategy, the revolution of ICT technologies has the capacity to facilitate sustainable innovations by reducing the amount of materials and energy needed while stimulating the economy so that sustainability becomes a "chosen direction" by the agents (Pérez, 2016) and so the potential of sustainability can accelerate if it is converted into an SC integrator backbone.

The results presented by this exploratory study would allow institutions and organizations to take more effective measures to progress aspects related to SC sustainability and, in particular, to improve municipal recycling problems from a broader point of view that includes, first, all agents in the same digital ecosystem and subsequently manage recycling as a sustainability value using for it PE advantages, corporate brand activism and human reinforcement elements. On the one hand, when these endpoints were included in the same digital ecosystem, sustainability value creation has advanced and, on the other when PE has been deployed, it has encouraged the possibility to capture it, exchange it and distribute it. The integration of these two perspectives in a single and ad hoc frame means to interweave reliably digital and programmable value based economy and management.

To achieve these objectives, a knowledge base has been acquired through a group of SC experts, and representative organization indicators have been used to calibrate the membership functions of the input and output variables. Through this knowledge, it was possible to extract the linguistic variables and their rules, making it possible to build a fuzzy inference system. Also, the system has been tested with real data on OECD and non-OECD cities using the Fuzzy Logic Toolbox from Matlab.

In this research, the objective of which is to reduce the negative externalities generated by household unrecycled waste using fuzzy systems (Mamdani inference) for diagnosing the problems of municipal recycling, considering some inputs (recycling policy focus, recycling orientation and programmable economy) and regarding the Environment Corporations Citizens Programmable Economy Model (ECOCIPEM), which is inspired by the ESE framework formulated by Ashford and Hall (Ashford *et al*., 2011) and reinforcement theory. These inputs are not exhaustive of the complex urban waste-recycling framework, but they have a large impact on it. It is been observed that by using the FISMUR algorithm and keeping the urban policy recycling focus variable constant by each country, the impact of deploying corporate recycling activism with a citizens' recycling incentive strategy base that rewards sustainable recycling through PE technology is greater than if recycling was done in isolation; presenting both options has a high impact in terms of increasing municipal recycling.

The benefits of applying the proposed fuzzy inference system may vary, depending on the initial level of policy recycling focus (sustainability policy index and municipal recycling relationship). Regarding this point, it is observed that there are limitations in the country "sustainability policy", thereby affecting the ability to take advantage of the benefits of the other inputs. In this sense, deploying recycling-oriented initiatives requires at least a medium-level-of-sustainability policy to be effective. Therefore, cities without a minimum-level-of-sustainability policy should prioritize investing in one first to subsequently reach a certain level of environment policy that allows them to capitalize on other initiatives. Likewise, from a certain level of country recycling focus (medium-high), the best initiatives to increase recycling levels apply both recycling-oriented initiatives (corporate activism and incentives that influence citizen behaviour) and PE initiatives and do not focus so much on only improving environment policy. The initial country recycling focus level is a key aspect of assessing the application of more advanced initiatives. Therefore, developed SC can start deploying RO and PE initiatives because they have great levels of digital adoption and customer focus; meanwhile, early city developers first need to invest in and improve their environment policy to achieve a recycling policy focus tipping point that permits them to take off, and, second, early city developers need to combine RO and PE initiatives with the expansion of digital adoption and customer-oriented initiatives. Thus, it cannot be affirmed that the same level of recycling focus corresponds with the same level of municipal recycling because there are specific variables for each city that are very important, such as population density; cultural aspect; and economic variables, such as GDP per capita and the Gini index.

This article also highlights the possibility of exploring the treatment of other negatives externalities generated in cities through the PE as a facilitator and integrator tool. The set of concepts that this technology includes will all be of vital importance in the future. This article promotes citizens' participation in city decision-making and promotes transparent, reliable, monetized, peer-to-peer and decentralized corporate recycling activism to open a new way for urban managers to explore negatives externalities or other issues. In no way is this study intended to minimize the role of institutions; in contrast, it seeks to provide them with technological capabilities to find new modes of fairer management efficiency and dissuade citizens and corporations from generating negative footprints and encouraging them to contribute to generating a more sustainable city.

This article has some limitations. It should be noted that this approach is in its first phase. At this moment, this research has only attempted to test the feasibility of the model to move on to the next phase. As for other limitations, this paper does not address the important technologies needed to implement the PE, such as 5G, artificial intelligence, big data, the machine-to-machine economy and cryptography. Additionally, this article does not include other variables of great relevance and very high impact included in the environment-social-economy (ESE) framework paradigm formulated by Ashford and Hall (Ashford *et al.*, 2011), such as legal aspects, taxes, user profiles, government policies and many more.

As part of future research, it is planned to add new variables to the proposed system such as type of reward, the target group in question and the value of the reward because, as it has been seen in theoretical background section, all of them are being testing in some cities and data could be available for it study. On the other hand, it could be analysed other results derived from this work, such as the impact of increased recycling and data collected on SC management or the effects of this impact on corporate marketing campaigns and to consider the possibility of applying PE and diffuse systems to the treatment of other urban externalities.

Conclusions

The aim of this thesis has been to explore the implications of adopting a digital ecosystem vision and determine its real and close PE applications when real and digital endpoints can be connected in the same value network, pursuing one mission. Regarding this point, differences in DT visions have been presented in nations, and the "Internet of value" has been used in the form of PE applications in cities.

Indeed, it has been described that there were some differences in countries value added performance when digital input has been seen in isolated manner or such as a digital ecosystem, concluding that last one has a better probability to push country's value added.

On the other side, cities' exploratory works have been focused on to enlighten PE possibilities, so they could contribute to solving significant concerns in them, such as sustainability, when it is used as integrator tool that allows to connect the physic and the digital worlds in one mission by capturing, exchanging and distributing value through the monetization.

The following chapter summarizes the principle arguments of this thesis: that there are different perspectives related to the DT, such as digital ecosystem or how to create value and, several deployment possibilities such as cities' PE sustainability applications or how to monetize the value. Both perspectives have been seen during this thesis and, as it will be seen in the general conclusions section, the alliance between them allows to answer the main question of this thesis.

All of these points have been reflected by developing models and methodologies to create knowledge in the field.

7.1. Executive Conclusions Summary

Tables 7.1 and 7.2 summarize the main results and conclusions of this thesis in relation to the initial objectives. In the following section, these points are disclosed in greater detail by reviewing the implications of each chapter, along with the limitations of the studies and potential future research directions.

Table 7.1 Summary of Results

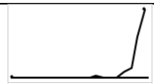
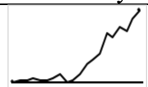
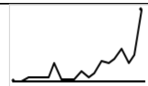
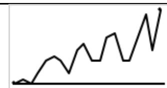
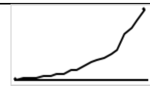
Chapter	Hypothesis	Model	Methodology	Results
3	H_1: Given a country sign value of the $DESI^+$ with respect to the EU28 average, there is a greater probability of having GVA^+ from its digital ecosystem indices $DESI^+$and $CEI^+$with respect to the EU28 average than having it come from its $DESI^+$ index in isolated mode. H_2: Given a country sign value of the $DESI^-$with respect to the EU28 average, there is a greater probability of having GVA^- from its digital ecosystem indices $DESI^-$and CEI^- with respect to the EU28 average than having it come from its $DESI^-$ index in isolated mode.	Digital Ecosystem Model (DEM)	-Conditional Probability/ Bayes' Theorem -Compound Annual Growth Rate (CAGR)	Confirmed H_1 and H_2
4	H_1: Negative incentives (congestion pricing, CP) applied to (private and commercial) unfriendly vehicles contribute to better mobility in cities. H_2: Positive incentives (non-congestion pricing, UP) applied in friendly vehicles contribute to better mobility in cities. $H_{3\,(1,2)}$: Negative incentives (congestion pricing, CP) applied to (private or commercial) unfriendly vehicles combined with positive incentives (non-congestion pricing) applied to friendly vehicles by the token economy (congestion pricing digital asset) and anchored in the IoT and DLT technologies contribute to better mobility in SC (reduce city congestion, improve institutional efficiency and recover city productivity) to a greater extent than H1 or H2.	Smart Congestion Management Model (SCMM)	Forgotten Effects (Kaufmann *et al.*, 1988)	Confirmed H_1, H_2 and $H_{3(1,2)}$

5	Q: The big question is knowing whether deployment of the programmable economy, together with the implementation of positive and negative incentives for the use of friendly and unfriendly vehicles in a defined area of the SC, can reduce traffic levels more than if only positive and negative incentives are used without PE, maintaining city structural fixes.	Structure-Conduct-Performance Urban Congestion Model (SCPUCOM)	Fuzzy Sets Theory (Zadeh, 1975) Mandami Fuzzy Method (Mandami, 1977) Toolbox Fuzzy Logic (Matlab, 2018)	Model has shown the greatest potential for reducing urban congestion. Savings of time were obtained if deployment of the variable conduct and PE was carried out at the same time and was not conducted in isolation, keeping the structure variable (infrastructure) constant.
6	Q: The big question is knowing whether the implementation of recycling incentives, with a city recycling policy focus and corporate recycling activism, all integrated with the programmable economy, can increase municipal recycling rates more than the implementation of citizen incentives and corporate activism without a PE, maintaining a city policy fix.	Environment Corporations Citizens, Programmable Economy Model (ECOCIPEM)	Fuzzy Sets Theory (Zadeh, 1975) Mandami Fuzzy Method (Mandami, 1977) Toolbox Fuzzy Logic (Matlab, 2018)	Model has shown that the greatest potential for municipal recycling obtained from the variable recycling oriented (RO) and PE carried out at the same time and not recycling oriented in isolation, keeping the recycling policy constant. PE has produced a significant and positive "level change" effect in the variable regarding municipal recycling.

Source: The author

Table 7.2 Summary of Conclusion

Original Objective	Status	Summary of Conclusions
Primary O_1: Present the state of the art of Digital Transformation	Achieved	Digital transformation landscape and its potential applications are currently a very important topic of debate due to their impact on the economy, society and management.
Secondary $O_{1.1}$: Bibliometric analysis $O_{1.2}$: Conceptual framework related to Digital Transformation, Digital Economy, Digital Assets, Blockchain and DLT, Smart Cities, Reinforcement and Sustainability	Achieved	The bibliometric analysis allows for concluding growing interest in all aspects analysed in this thesis. Publication evolution over a period of time from 2000 to 2018 is shown:

Digital Transformation	Digital Economy	Digital Assets	Blockchain and DLT	Smart Cities	Reinforcement	Sustainability
						

Original Objective	Status	Summary of Conclusions
Primary O_2: Discuss and develop a novel framework to support policy-makers, countries, cities and businesses address the potential value that can be generated and captured by digitalization through new perspectives about Digital and Programmable Economy in countries and Smart Cities by new models and frameworks using some methodological approaches.	Achieved	A digital ecosystem approach can be used to develop a more robust approach to digital transformation, providing new implications for the macro and micro economy, business and management. Equally, the importance of the "Internet of value", developing real applications in cities, can contribute to resolving sustainability challenges when sustainability is managed as a value through PE combined with citizen participation allowing organizations, corporations and consumers to work together focusing on the same mission. As a main conclusion, if agents wants to create or capitalize value in the digital age such as sustainability, they should consider to build their own digital and programmable value based economy and management (DIPVABEM) frame as it shown in Figure 7.1, in two lines, the digital ecosystem and reliable monetization by PE including human centric vision.
Secondary: $O_{2.1}$: Discuss the implications of actual digital transformation factor in countries as a multidimensional point of view.	Achieved	Actual nations' digital transformation phenomena as contributors to their progress are missing an integrated point of view and partial measure, compared to the digital ecosystem. Using the Digital Ecosystem Model and Digital Ecosystem Equation combined with conditional probability methodology, some hypotheses are exposed in Chapter 3, revealing that positive GVA^+ has a poor probability of being obtained with any combination of the DESI and CEI

		indices with different signs. At the same time, a negative combination of these indices translates into a greater probability of having a negative value of GVA^{-} in any EU country. In contrast, countries with positive combination of them have a greater probability of attaining better GVA values.
$O_{2.2}$: Argue the advantages of deploying end-to-end digital solutions and digital assets as a multidimensional approach.	Achieved	The advantages offered by some digital disruptive technologies, such as the Internet of Things (IoT), blockchain/distributed ledger technology (DLT), smart contracts, digital assets and the token economy, combined with a human capital aspect such as reinforcement theory explained in Chapter 4, allow more sustainability city. All of these advances allow for the connecting of citizens, organizations and things to exchange all types of values, as such tangible or intangible values such as congestion spillover effects, thanks to digital assets monetizing and reinforcing transparency and decentralizing and trust increasing city sustainability.
$O_{2.3}$: Explore some PE applications in smart cities managing digital value exchange between participants following sustainability.	Achieved	Using SCMM, SCPUCOM and ECOCIPEM models acting as a digital ecosystem, forgotten effects and fuzzy logic methodology, some exploratory work appears in Chapters 4, 5, and 6, concluding that, the use of the PE application as a tool that allows monetize sustainability as a value, combined with citizen participation, have a greater impact on improving sustainable city problems, such as urban congestion or waste management. Additionally, PE increases productivity and institutional efficiency at the same time. The initial city infrastructure level, environmental policy and digital economy phase (installation or deployment) are key aspects for assessing the application of more advanced initiatives such as PE. Equally, PE allows organizations to deploy a sustainable outside-in vision connecting value endpoint and key players in the same objective, pushing value creation, and pulling value capture, exchange and distribute.
O_3: Primary Publish some articles to develop digital and PE practical cases and useful applications.	Achieved	*Beyond Digital Transformation Race.* Article published in "Digital Transformation and Artificial Intelligence, Towards an Efficient and Equitable Model", (III Catalonian Economy and Business Congress, 2018) D.L. B-1804-2018, ISBN 978-84-09-04059-9
	Achieved	*Digital Assets Horizon in Smart Cities: Urban Congestion Management by IoT, Blockchain/DLT and Human Reinforcement.* Article published in "Modelling and Simulation in Management Sciences. MS-18 2018. Advances in Intelligent Systems and Computing", vol 894. Springer, Cham, DOI https://doi.org/10.1007/978-3-030-15413-4_6 (Scopus Cite Score 2017: 0.40)

Secondary: $O_{3.1}$: Diffusion: Participating in some congresses and conferences	In Revision	*Digital and Programmable Economy Applications: A Smart Cities Congestion Case by Fuzzy Sets*. Article in revision to the *Journal of Intelligent & Fuzzy Systems*. The title of the special issue is: Information and fuzzy Systems in Management Science-(Impact Factor JCR 2017: 1.426).
	Submitted	*Sustainable City by Connecting Critical Endpoints*. Article submitted to *Journal Computer Science and Information Systems*- The title of the special issue is: Information Systems and Business Intelligence in Management Science (Impact Factor JCR 2017: 0.613)
	Presented	*Beyond Digital Transformation Race* 1 - Second On/Off International Conference in Marketing Decision Making, October 2017 2 - Third Economy and Business Congress, May 2018
	Presented	*Digital Assets Horizon in Smart Cities* 3 - International Conference on Modelling and Simulation, June 2018 4 - Third On/Off International Conference in Marketing Decision Making, November 2018
	Presented	*Digital and Programmable Economy Applications* 5 - Fifteenth International Conference on Technology, Knowledge and Society, March 2019

Source: The author

The conclusions of each chapter and its contributions are presented below to show the contributions of this thesis with a greater level of detail

7.2. Chapters 1 and 2 Conclusions

In these first two chapters, the bases have been established that explain in a preliminary way the content of this doctoral thesis. First, the motivations, objectives, methodologies and contributions of the research was described in the introduction. Second, the state of the art was presented from the bibliometric point of view through the Web of Science database, which establishes relevant information about the main topics of the study. In addition, basic concepts of digital transformation, digital and PE, blockchain and DLT, digital countries and digital SC were presented, as well as important concepts related to this thesis, such human reinforcement, sustainability and brand activism. As it has been seen, all of these topics have a positive publications trend and notorious relevance in the academia contributing for understanding the problems that revolve around digital transformation in a broad sense and the opportunities that its offers in regard to contributing to the design of some applications to overcome the great problems that currently affect humanity, such as sustainability

7.3. Chapter 3 Conclusions

Based on the Digital Ecosystem Model, DESI and CEI as an aggregator of different macroeconomic variables with large impacts on productivity, such as competitiveness, innovation, employee engagement, have been used. These indices were treated together through the application of the Bayesian conditioned probability methodology, that allows for better decision making (Berenson, 1992), related to countries' GVA. The model has confirmed the two hypotheses, verifying that the majority of countries with the best performance in GVA sign values also have a better CEI and DESI indices than the EU28 average. In other words, if countries drive innovation, competitiveness and employee engagement and add the digital factor to increase all of them, the effects on the GVA will have a high probability of being favourable, achieving consistent DE development.

As a main conclusion, it was shown that countries with high digital ecosystems have a greater probability of attaining better GVA values than medium or low ecosystems. Consequently, there are two stages related to DT: a first stage in which the countries are focused on installing tech elements; and a second stage of deployment, in which countries have overcome the first stage and have started to combine and exchange digital endpoints obtained from industries more likely to generate value, confirming digital transformation stages (Van Ark, 2016).

Overall, country digitalization and its implications require a vision that considers the ecosystem that the digital nerve affects. Advances in the digital index only in a technological way do not guarantee country GVA growth and have less important magnitude when innovation, competitiveness or employee engagement, among many other factors, are stagnant. Digital transformation requires a solid and growing foundation of a strong and consistent digital ecosystem considering technology and other productivity aspects to exploit its full potential by connecting value endpoints. In addition, public and private policies should be fundamental, ensuring actions to advances digital, innovation, competitiveness and labour engagement variables jointly to ensure with a better probability that the digital ecosystem will increase country value added, knowledge creation and endpoints connection while avoiding an increase isolated to technology.

Thus, technology is necessary but not sufficient. This article was published in "Digital Transformation and Artificial Intelligence, towards an Efficient and Equitable Model" (III Catalonian Economy and Business Congress, 2018) D.L. B-1804-2018, ISBN 978-84-09-04059-9.

7.4. Chapter 4 Conclusions

In this chapter, the Smart Congestion Management Model (SCMM) was presented. With this new model, the benefits of the Theory of Human Reinforcement (Skinner, 1953) were exploited, along with the advantages of the digital assets, blockchain and IoT unifying and integrating element of an urban mobility model. It was seen that they mitigates the effects of congestion in cities allowing for the monetizing of congestion externalities and the redistribution of the incentives for the participants that operate in them. To determine the validity of the model, a pool of experts and the Forgotten Effect Theory (Kaufmann *et al*., 1988) were used, analysing direct and indirect incidence relationships.

As a major conclusion, it was observed that mixing digital inputs, agents and human motivations in the same digital ecosystem has a greater impact on improving urban congestion, city productivity, and institutional efficiency than the use of congestion taxes or "non-congestion" ones in isolation.

Thus, urban congestion problems (productivity, environment or human health) and their solutions could be approached not only under the tech umbrella or congestion price tax but also by mixing holistic perspectives to include other variables, such as human motivational aspects, encouraging endpoints connection and exchanging sustainable value between participants to balance externalities and shift urban models ahead from 1.0 to 2.0, advancing from the "Internet of information" to the "Internet of value" increasing sustainability.

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7.5. Chapter 5 Conclusions

From exploratory work, using the Structure-Conduct-Performance (SCP) model (Bain, 1956) the Structure-Conduct-Performance-Urban-Congestion Model (SCPUCOM) has been obtained. To determine the validity of the model, a pool of experts and Fuzzy Set Theory (Zadeh, 1975) and especially the Mandami inference method (Mandami *et al*., 1975) and the development of an inference algorithm were used. Thus, based on a set of rules established by experts in the field, the values of urban congestion output have been determined based on some inputs included in the FISUC algorithm. Finally, using the Matlab Toolbox (Matlab, 2018), predictive urban traffic congestion has been studied by cities.

As a main conclusion, the use of the PE application as a tool that allows monetize sustainability as a value, combined with digital ecosystem and citizen participation has had beneficial effects in reducing urban congestion and increasing efficiency management, obtaining positive productivity consequences for cities. The integration of these perspective in one means to interweave a particular sustainability digital and programmable value based economy and management frame. It should be noted that cities without a minimum level of infrastructure should prioritize investing in it first to subsequently attain a certain level of infrastructure that allows them to capitalize on other initiatives, such as PE. Similarly, from a certain level of city structure (medium-high), one of the best initiatives to reduce congestion levels is the application of citizen incentives and PE applications at the same time, which does not focus as much on improving infrastructure only.

The initial city infrastructure level is a key aspect for assessing the application of more advanced initiatives. Thus, developed SC can accelerate their digital deployment phase using PE, while early cities developers should invest in and improve their infrastructures first to achieve structural tipping points that allow them to take off and subsequently combine with PE and take advantage of it. In contrast, it has been seen that increasing citizens' participation in city decision making by exchanging sustainability value in a transparent, reliable, monetized, peer-to-peer and decentralized manner has opened up new opportunities for urban managers to explore externalities management or other issues, encouraging them to contribute to generating a more sustainable city.

This article is in revision to the *Journal of Intelligent & Fuzzy Systems*. The title of the special issue is: Information and fuzzy Systems in Management Science-(Impact Factor JCR 2017: 1.426).

7.6. Chapter 6 Conclusions

In this exploratory study, another digital application was developed to contribute to devising new models that could render cities more sustainable. Based on the Environment-Social-Economy (ESE) model (Ashford *et al.*, 2011), the Environment Corporations Citizens Programmable Economy Model (ECOCIPEM) was developed to increase recycling in cities. Bearing in mind that there are no simple solutions to coexisting with a high degree of imprecision regarding the measure of the concepts contained in the model, the Fuzzy Set Theory (Zadeh, 1975) and especially the Mandami Inference Method (Mandami *et al*., 1975) by inference algorithm and a set of rules established by experts in the field, the municipal recycling value was obtained as an output. Finally, using the Matlab Toolbox (Matlab, 2018), the predictive results of urban recycling rates for several cities were illustrated.

The results presented could allow institutions and corporations to undertake more effective measures to improve municipal recycling rates from a broader point of view that includes the PE, corporate brand activism and human capital elements, all pursuing sustainability in cities.

As a main conclusion, the use of the PE application as a tool that allows monetize sustainability as a value, combined with digital ecosystem mindset and agents participation has had beneficial effects in increasing urban recycling in cities. In addition, the impact of deploying corporate recycling activism with a citizens' recycling incentive strategy based on sustainable recycling rewards through PE technology application has had better results than if recycling were undertaken in isolation. The integration of these perspectives in one means to interweave a particular sustainability digital and programmable value based economy and management frame.

As shown, the benefits of applying the proposed fuzzy inference system can vary, depending on the initial level of policy recycling focus. In this sense, deploying recycling-oriented initiatives requires at least a medium level of sustainability policy to be effective. Therefore, cities without a minimum-level-of-sustainability policy should prioritize investing in it first to attain a certain level of environment policy that allows them to capitalize on other initiatives. Similarly, from a certain level of country recycling focus (medium-high), the best initiatives for increasing recycling levels would apply both recycling-oriented initiatives (corporate activism and incentives that influence citizen behaviour) and PE initiatives, avoiding focusing as much on improving environment policy exclusively. Thus, it was seen that PE as a digital application has increased sustainability value exchange between agents, achieving better results in integrating and connecting cities' value endpoints.

Equally, cities' digital economy stages (installation or deployment) (Van Ark, 2016) or different stages from the "Internet of information" to the "Internet of value" could also influence whether PE applications succeed.

This article has been submitted to the *Journal Computer Science and Information Systems*. The title of the special issue is: Information Systems and Business Intelligence in Management Science (Impact Factor JCR 2017: 0.613).

7.7. General Conclusions

Returning to the starting point of this thesis and formulating again the main research question, "*In the fields of economics, business and management, how could digital transformation advance (push) value creation and reliably encourage (pull) value capture, exchange and distribution?",* a summary of conclusions are illustrated.

In order to answer this question this thesis has been focused on to explore, concrete issues related to, first, how to DT can advance GVA among countries' producers and second, how DT can encourage sustainability value in cities for, after that, to find out a broad answer useful for agents.

As a general conclusion, it can be seen from a comprehensive point of view that, the current digital transformation in nations is having different results. Countries with high digital ecosystem visions are using digital transformations more as a knowledge connector input between agents that to allow them to obtain synergies over important variables, such as innovation and competitiveness, or human multipliers, such as employee engagement, at the same time. Thus, these countries have been obtained more probability to have favourable and consistent results in their value added over a period of time rather than countries that they used digital factor in isolated mode forgetting scan these variables. It has been seen that nations with medium or low digital ecosystem and that exclusively seek to increase their digital vertex, neglecting variables cited above, have a greater probability of having worse value added performance, despite the last ones showing good digital momentum. In conclusion, the countries with ideas commented during this thesis, such as a unidimensional digital mindset, digital momentum obsession, prolonged digital installation stage, doing digital mindset or disconnected public and private policies, could have a poor probability of having good GVA performance, compared to countries attempting to increase their GVA thanks to understanding the digital transformation as a digital ecosystem connecting knowledge anchoring their strengths through a multidimensional digital mindset, deploying strong digital ecosystems, avoiding digitization, being digital mindset, and knowing how to integrate agents and public and private policies all of them in order to push value. Thus, last ones are confirming that digital technologies can have considerable impacts on countries' value advance when ICT are combined with investments in complementary assets and knowledge endpoints are connected acting together as a digital ecosystem.

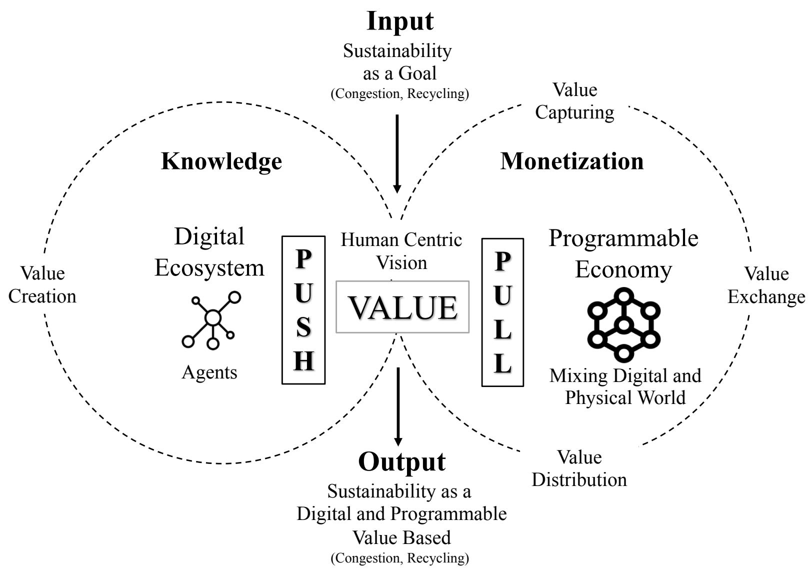
On the other side, from a more concrete perspective, specific applications of the "Internet of value" have been exposed in order to materialize sustainability as a value in cities. Regarding this point, exploratory works have been conducted to determine the potential contributions of DT to providing new approaches that allow cities to face their current problems related to sustainability, such as urban congestion and urban recycling. In this way, it has been possible to show that: first, the construction of several models that act as a digital ecosystems such as Smart Congestion Management Model (SCMM) in Chapter 4, Structure-Conduct-Performance Urban Congestion Model (SCPUCOM) in Chapter 5 and Environment-Corporations Citizens Programmable Economy Model (ECOCIPEM) in Chapter 6, have advanced sustainability value creation by sharing knowledge between agents.

Second, it has been possible to capture sustainability as a value as an example of PE potential through it deployment doing possible to be captured, exchanged and distributed it in trusted way, in others words monetized it reinforcing agents' integration interweaving real's and digital's endpoints. Indeed, it has been seen how to operate at the same time with things, people, and organizations was possible thanks to the use as concepts such as digital asset, blockchain, monetization and smart contracts in cities.

In terms of results, it was seen through several simulations that PE deployment presents a positive level change in current sustainability trends in terms of congestion reduction and recycling increases in cities. In addition, it was seen that all of these changes were possible to be implemented in a transparent trusted manner, reducing transaction costs and permitting organizations to work in a more fluid management manner, rather than a frictional one.

Overall, in order to answer the main question of this thesis and, taking into account that, the capture of the vast majority of the immense digital value potential is not guaranteed and its distribution between agents is no clear, it is necessary to join all the aspects that it have been included in the conclusions section explained above, in order to propose a frame that helps the agents to deploy their digital initiatives that ensure to create, capture, exchange and distribute that value reliably. Thus, it can be said that while digital ecosystem over different dimensions such as a country, city or corporation advance (push) value knowledge creation by connecting agents' endpoints, the PE application allows to encourage (pull) it through the monetization, combining the real's and digital's world at the same time and capturing, exchanging and distributing it among the agents in decentralized and trusted way. So, digital transformation can be a value driver if that it use the Digital Ecosystem mindset and can be a value grabber if that it use PE applications at the same time, contributing to solve the digital value materialization. As it has been seen during this thesis, big issues such as sustainability can be managed by digital value point of view. If so, it needs this two approaches (push and pull) simultaneously. The integration of these two perspectives in single frame means to interweave a particular digital and programmable value based economy and management (DIPVABEM) frame as it is shown in Figure 7.1, as an example of sustainability as a value.

Figure 7.1 Digital and Programmable Value Based Economy and Management Frame



Source: The author

For whatever dimension (country, city, organization) or purpose (economic, business or management) such as sustainability in cities or other, if agents want to advance value creation and encourage the reliable monetization of it in the digital age, they should consider to build their own DIPVABEM frame in two lines; first, pushing all functional agents' endpoints connections in the same digital ecosystem from a holistic point of view in order to advance knowledge and value creation, and second, if they want to monetize it in a decentralized, transparent and reliable way, they need to mix digital's and analogue's world using PE applications pushing the value capturing, exchanging and distributing it between the agents ensuring their balance. Finally, a DIPVABEM successful needs to consider that agents should include in it social centric vision and human reinforcement without forgetting that, current big issues such as sustainability, requires to embody multiple transdisciplinary visions.

This new framework invites to evolve over some economic, business and management digital' perspectives (From-To) in organizations and institutions. A brief summary of them appears in Table 7.3.

Table 7.3 Digital and Programmable Value Based Economy and Management "From-To"

<table>
<tr><th colspan="3"></th><th>From</th><th colspan="3">To</th></tr>
<tr><td rowspan="5">Push Value</td><td rowspan="5">Digital Ecosystem</td><td rowspan="5">Value Created: Sharing Functional Knowledge</td><td>Unidimensional</td><td colspan="3">Multidimensional Digital Mindset</td></tr>
<tr><td>Digital Installation</td><td colspan="3">Digital Installation and Deployment</td></tr>
<tr><td>Digitization</td><td colspan="3">Digital/Digitalization</td></tr>
<tr><td>Doing Digital</td><td colspan="3">Being Digital</td></tr>
<tr><td>Disconnected Public and Private Policies</td><td colspan="3">Integrated Public and Private Policies</td></tr>
<tr><td colspan="7">Human Centric Vision</td></tr>
<tr><td rowspan="10">Pull Value</td><td rowspan="10">Monetization</td><td rowspan="10">Value Capturing/ Exchange/ Distribution</td><td>Isolated Agents</td><td colspan="3">Involving Agents</td></tr>
<tr><td>Low Policy and Government / Agents Commitment</td><td colspan="3">High Policy and Government / Agents Commitment</td></tr>
<tr><td>Low Focus on Problem Solving</td><td colspan="3">High Focus on Problem Solving</td></tr>
<tr><td>Centralized</td><td colspan="3">Decentralized</td></tr>
<tr><td rowspan="6">Economy</td><td rowspan="6">Programmable Economy</td><td>From</td><td>To</td></tr>
<tr><td>"Internet of Information"</td><td>"Internet of Information" and "Internet of Value"</td></tr>
<tr><td>Data Exchange</td><td>Data and Value Exchange</td></tr>
<tr><td>Frictional Exchange Management</td><td>Fluid Exchange Management</td></tr>
<tr><td>Assets/ Liabilities</td><td>Digital Assets/ Liabilities</td></tr>
<tr><td>Untrusted</td><td>Trusted</td></tr>
</table>

Source: The author

As it has been seen, DIPVABEM frame is a suitable tool for countries, cities and corporations in order to understand DT and PE opportunities over digital value potential creation and capture and find out new approaches over current issues such as value added growth, sustainability as a social value promotion or it potential application over others subjects that it will be suggested afterward. Deeper detail about their research and managerial implications are shown in the next section.

7.7.1. Research Implications

The first implication of this thesis is that DT analysis involves abandoning exclusively one-dimensional research focusing on exclusive technological performance for approaches in favour of multidimensional or ecosystem approaches, reinforcing a systemic vision in which the total forces are clearer. This integrating vision turns out to be a great challenge for researchers since it is more difficult to integrate tools and disciplines than to apply them separately (Senge, 2012). Regarding this difficulty, in Chapter 3, some of these issues were explored, presenting an approach that does not looking for causality with the variables among themselves and explores, from a broader point of view, the synchronization of them. In this way, the type of question behind the research objective avoids formulas relating to how two events are related and focuses more on what events might be linked, determining whether there is any way to link their content towards the same end by taking advantage of the synergies included in them to contribute to better decision making.

The second implication is that these results should be considered when agents analyse the potential digital transformations opportunities in order to contribute to create and monetize value in cities or reducing sustainability issues, such as urban congestion or recycling in cities. As seen in Chapters 4, 5 and 6, a significant advance could be achieved when concepts such as digital assets (Muth, 2019), sustainability as a value (Elkington, 2004; United Kingdom Green Building Council, 2018) and smart contracts (Szabo, 1996) are used by agents because they open the door to managing negative spill-over effects in a different ways; as a result, they can be registered in a binary format and cities' institutions or organizations can activate the rights to use them, all inside a single network solution such as blockchain or DLT with a history that cannot be altered. Thus, they can use at the same time the rule of "if this, then that" in smart contracts (Nikogosian, 2019), including facts related to sustainability since, is it considered that sustainability will be one of the most important business value-created drivers of organizations and institutions in the future (United Kingdom Green Building Council, 2018).

In addition, it was seen how the mixture of citizen participation and human centric vision with technological solutions has turned out to be a good combination that allows for materializing advances towards SC 2.0, seeking to move beyond infrastructure interconnection towards optimization in the decentralized decision-making. Furthermore, the jump from the "Internet of information" to the "Internet of value" can be materialized by a trusted PE backbone, verifying total participant integration in the same reliable network supported by intelligent contracts making it possible to capture, exchange and distribution value between several agents. Regarding this matter, the fact that PE allows to exchange value and information in a reliable, decentralized and transparent way implies being able to advance in explore some models that safeguard more the privacy of the agents. The anonymity in blockchain records protects individual from being targeted in the fight against powerful organizations, unlike with other system that its currently being tested in China such as Social Credit System. This system it's trying to integrate traditional commercial credit rating into social behaviours, involving centralized data and it is being used to monitor government affairs, judicial affairs, social activities and commercial behaviours, offering a reward and punishment centralized mechanism (Xu et al., 2018). These factors invites institutions, organizations and researchers to reflect on how the tomorrow´s cities and countries should be.

The third implication revolves around the fact that, the DIPVABEM frame allows knowing what the agents' purpose is over the digital transformation. As it has been seen along this thesis, some exploratory cases were done it towards the creation of value by digital ecosystem in Chapter 3 and other towards exchange, distribute or capture of it in Chapters 4, 5 and 6. The results obtained allow agents facing the DT´s solutions in different perspectives depending on whether they want to reinforce value creation pushing agent' knowledge endpoints connections or by contrast, they want to manage it by exchanging it, working all the agents in the same mission mixing real and digital endpoints thanks to the PE. In this sense it's important to highlight that, if they want to accomplish the second part, agents need to know previously what digital ecosystem is working on in order to build the appropriate model that allows them to capture, exchange and distribute value later, as it has been seen in several models contained in the prior chapters.

The fourth implication is that the data contribute to a much clearer understanding of the importance of public and private policies related to infrastructures, legal policies and regulations in digital transformation and sustainability. All of these factors are very important factors increasing value added in countries and sustainability value exchange in cities. As seen in Chapter 3, public policies are a critical factor contributing to moving from the digital installation stage to the digital deployment stage, confirming the idea of different digital transformation stages (Van Ark, 2016) and thus digital ecosystem intensity. This second stage allows for maximizing the network effect of the digital ecosystem by connecting other progress variables, such as innovation, competitiveness or engagement, allowing for an increase in countries' value added and productivity (Ross, 2017; OECD, 2017). Thus, if countries want to achieve an increased digital transformation effect, they will need to ensure hard investments in public and private policies focusing on digital aspects and progress aspects at the same time, managing them and capturing their synergies.

According to this, it was shown in Chapters 4, 5 and 6 that infrastructures, regulations and public policies have been critical inputs in the fuzzy inference algorithm used to capitalize on PE effects and then to increase sustainability value exchange. Furthermore, cities without a minimum level of infrastructure (United Nations, 2016) have been excluded for deploying PE, and it has been recommended to them to start investing in infrastructures first and subsequently to combine it with PE applications. Moreover, regulations were a critical factor in this chapter. The exploratory results have shown that, without sustainable regulations or smallest level regulations, PE effects are reversed, so the multiplier effects of PE could be captured when the starting point of regulations or policies towards sustainability is medium or high.

The fifth implication is related to sustainability orientation in two ways: the effect on participants when they have been rewarded by their sustainable decisions and corporations' implications for it. It was shown in Chapters 4, 5 and 6 that the initial level of citizens' sustainable orientation is a very important factor, followed by the participants' sensitivity level or the attractiveness for them of positive or negative rewards (Bell *et al.*, 2013). It was seen that, when this level was low or high, it affected in final actions confirming Reinforcement Theory (Skinner, 1953). Thus, at the same level of citizens' sustainable orientation, if its accompanied by PE applications, it effect was more prominent over sustainability value exchange between participants. In addition, in Chapter 6, corporation brand activism input played an important role in recycling indices in cities. Thus, there is no doubt that the corporations' implications for city sustainability or other subjects related to digital value, have been a critical factor since the beginning, and if it is high or low, it will affect the expected PE application return, the future effectiveness of it and the amount of sustainability value exchange generated between participants.

Finally, the exploratory analysis in all of the chapters provides new insights into the relationship between agents such as public and private organizations, institutions and citizens or consumers and how they can operate together in one mission. As seen in Chapter 3, digital ecosystem adoption has confirmed that is a critical factor for realizing more transversal connections between platforms to inspire rapid innovation and greater value added and productivity growth (Gartner, 2017) in countries. In addition, it was shown in Chapters 4, 5 and 6 that PE applications contribute to defends the idea that many of the resources that nature provides cannot be replaced by products or services made by human beings, arguing the first principle of thermodynamics, which is included in the SSE model (Czech *et al.*, 2004), the objective of which is to keep the throughput of raw material (low entropy) and waste (high entropy) at levels within the regenerative and assimilative capacity of the ecosystem. Therefore, PE deployed in a sustainability task is moving away from the neoclassical economic view (Solow, 1993), which sees growth as a continuous expansion, to the SSE model, in which the economy must be in permanent equilibrium with the ecosystem in which it operates (Ashford *et al.*, 2011). According to this, PE applications have the capacity to facilitate sustainable innovations by reducing the amount of materials and energy needed while stimulating the economy so that sustainability becomes a "chosen direction" by the agents (Pérez, 2016). All of that allows for advancing cities from "doing digital" mindset, or how to use all tech available, to "being digital" or putting people first and using technology (Cognizant, 2016) in order to raise sustainability.

7.7.2. Managerial Implications

The first managerial implication of this thesis, shown in Chapter 3, highlights the importance of digital ecosystem management as a reinforcement of interoperability, mixing technological indicators and others related to the progress of nations.

Second, in this chapter, public and private policies were described that should be reconsidered, ensuring join actions to boost the variables related to DT, innovation, competitiveness and social engagement. Additionally, country agents wanting to pass from the "Internet of information" to the "Internet of value" will demand that institutions focus more on investing in tech elements exclusively, being careful to create consistent connections between their progress drivers, which truly allow organizations to generate value. In this sense, mixed indices could be created by institutions that contain both types of technological and non-technological variables to reinforce the digital ecosystem.

On the other hand, institutions and organization will need to work much closer in order to prioritize the value that they want to work understanding in deeper what kind of agent's endpoints connections could advance this value and, as it has been seen in Chapters 4, 5 and 6, what kind of digital and physical endpoints could exchange, capture or distribute this value developing their own PE applications following DIPVABEM framework that it has been seen. All of this open the door to embrace DT projects and its sustainability potential application through sharing public and private resources, talent and objectives involving on it the universities and multidisciplinary research centres.

The third implication is that the discoveries that this thesis proposes in Chapters 4, 5 and 6 signify a movement forward from centralized organizations (human-decision-human operation scheme) towards decentralized organizations, in which a group of people acts among themselves following a protocol defined in code and executed in the blockchain (Vivas, 2017), meaning that, in the decisions that take place in the cities, smart contracts can also participate by distributing power among the participants (citizens, institutions and corporations). In this way, the road will be paved to Decentralized Autonomous Organizations (DAO), which are the corporations in which the management function is automated by code, and the human element is removed (Buterin, 2013), coming closer to the idea of a Decentralized Autonomous Society (DAS) in which humans are "freed" from centralized institutions of power and control (Thorp 2015). So, the traffic management in cities, the incentives management dedicate to sustainable or healthy style of life or energy efficiency could be organized through these smart contracts and the artificial intelligence using DIPVABEM frame on their own interests and priorities.

The fourth managerial implication is that it should be noted that these chapters could cause organizations, cities and countries to consider their culture as a set of values and norms that guide human interaction, understanding the digital value that they hope to embrace in a digital age. According to Westeman (Westerman *et al*., 2019), key values of digital culture will be much more prevalent in the future, such as impact or constant innovation, speed or moving fast, openness or sharing and autonomy or discretion. Organization will need to know how people, organizations or citizen interact, how institutions will work and what types of roles that future organization will play to integrate all of them. Developing a digital culture does not mean doing away with a traditional one; rather, it is a combination formula. To carry out this task successfully, it is essential to maintain a balance between the values of traditional culture and future challenges through inclusive and redistributive public policies to maintain traditions without losing the digital challenge.

The fifth implication is that it should be noted that Chapters 3, 4, 5, and 6 invite public and private managers to reflect on their responsibility for the necessary and continuous training in ICT skills and sustainability mindset of their teams without forgetting to integrate citizens into it. Public and private organizations should exercise their roles as managers to fulfil their responsibilities regarding the application and performance of knowledge (Drucker, 2003) that offers digital transformation. On the other hand, sustainability awareness campaigns should be included, explaining digital ecosystem, PE potential, DIPVABEM frame mindset and how citizens, organizations and institutions can work together more effectively than in an isolated manner considering that organizations and corporations have an economic and moral responsibility to work hard to reduce unsustainability damage as much as possible (Winston, 2019).

In addition, institutional regulation and infrastructure activity should be a critical aspects and could be the most important for countries and cities that have not yet achieved the digital stage; being immersed in digitization, one thus cannot capitalize on DT advantages. The dissemination of continuing education programs related to sustainability and DT in schools, universities, companies and discriminated sectors will be fundamental.

The sixth implication is related to digital leadership. As a result of digital disruption and sustainability issues, leaders face new challenges. The digital ecosystem mindset in countries, the PE applications in cities, the sustainability as a value and DIPVABEM frame are not automatic but rather imply people's engagement and managers commitment; thus, they involve large changes in organizations. For instance, including working agents is a common objective in the digital age and is not only a connection issue since people need managing and leadership at the same time. Indeed, leadership is not synonymous with domination, but the art of convincing people to collaborate to achieve a common goal (Goleman, 2011) and DT input could be facilitators but cannot lead to this shift between tradition and the future by itself. To do so, organization requires digital and sustainability leaders with transformative and clear visions, purpose and direction, digital literacy, adaptability, forward looking attitudes, and collaborative minds (Kane *et al.*, 2019), all combined with a new level of performance to achieve key global sustainability challenges and deliver on this promise (United Nations, 2014). So, this leadership could be do it such as minor scale too. Local programs could be carried out at the neighbourhood level with a common project and where, through citizen collaboration, the local commerce participation, corporations and local authorities, incentives generated by sustainable behaviours could be used in order to invest in green areas and public services improvement.

The seventh implication of this thesis is related to the need to reformulate the vision of the networks that digitalization causes. As explained in Chapters 4, 5 and 6, the current hyperconnected and ICT systems are generating sophisticated connection networks. Through the DIPVABEM frame, the connections among people, things, machines and organizations could be increased among themselves, accelerating the so called machine-to-machine (M2M) network and human-machine-network (HMN) relations (Tsvetkova, *et al*., 2015). All of these new connections could have large impacts on organizations, both on the synergies that occur between them and on the design of decision-making processes drawn among governments, institutions, citizens, smart devices and sensors in the future. This new relationship could have substantial influence on tomorrow's society model.

To help to resolve these unpredictable frictions, in the chapters mentioned above, an approximation was made of how the DIPVABEM frame can contribute to smoothing these relations and improving human-machine agreements. In this way, the gap between human decision patterns -- determined by the perceptions of costs and benefits or motivations (Ardichvili, 2008, Skinner, 1953) that become more unpredictable by including aspects related to emotions, attitudes, and intentions with those of the machines, absent emotions and irrationality (Jia *et al*., 2012) -- could soften, integrating them into a common purpose. All this does not avoid the debate about who assists whom, if the machine assists the human or reverse. All this implies regulatory and legal challenges and induces a "fear of loss of control" (Intrator, 2018). Through the DIPVABEM frame, the routine decisions such as the monitoring of recycled materials, data management and information on cities' recycling habits or how to manage infrastructure can be coexisted with those that include more human aspects such as citizen participation and motivation through incentives.

The eighth implication is related to the traditional or analogue economy is moving towards the digital economy. The current stage in which the developed economies are located does not stop being to a state of transition to gradually on-going delegation of human decision making to technology. But it should not forget that, once this stage has been reached, economies, cities and corporations will be placed in the next stage, autonomous economy and management supported by an amalgam of platforms and disruptive tools such as PE leveraged on the artificial intelligence (Intrator, 2018). Thus, the challenge for managers will be do it without losing control and maintaining human centric vision.

The ninth implication delves into the importance and responsibility of the organizations', institutions' and corporations' managers to have an outside-in perspective (Manning *et al.*, 2016) in regard to fixing problems that occur in SC or nations such as sustainability. Thus, their value propositions should be centred on citizens', consumers' and environment issues rather than inside out vision, more focus on profitability. Therefore, countries, cities and corporations should understand DIPVABEM frame as an inclusive tool to embrace all agents participation in their decision-making processes. Therefore, a vision from the outside inwards makes it possible for organizations to return the prominence to their citizens or consumers by allowing a bottom-up decision making contributing to guarantee that digital value potential -valued in $100 trillion in the next decade (Martin *et al.*, 2018)- can be captured and distributed between society and industry.

The tenth implication of this study and contained in Chapters 4, 5 and 6 is that this thesis contributes to an alternative management of the spillover effect occurring in cities and therefore contributes to a new approach towards sustainability. The "Internet of value" allows for monetizing assets and liabilities or, in other words, makes it possible that spill-over effects become digital assets, allowing institutions to rethink the new models related to them. Thus, the monetization of externalities opens the door to reflect on current and future tax models and to determine tax burdens along the value chain participants (generators, intermediaries, consumers), the producer responsibilities through end to end formulas over recycling or others negative externalities that affect the health, nature or welfare of citizens such as pollution, unhealthy foods or tourist overcrowding in cities.

Finally, all agents involved in sustainability should rethink their positions going beyond traditional models, determining digital potentials. Sustainability seeks to solve great challenges. Nowadays one of the most important challenges is how to use digital and ICT advantages to drive SDGs progress such as digital value to society (DVS) (Martin *et al.*, 2018) focused on to capture this value. The urgency about sustainable development needs more profound political engagement and proactive governance because recent environmental research have revelated a faster than expected decline in natural ecosystem (Järvensivu *et al*., 2019). The incorporation of this new technology to meet sustainable targets can involve high costs and risks, but the cost of not doing something could be worse in the long run. For this reason, some organizations are stumbling in greenwashing short term visions that appear to limit the environmental impact without actually doing so (Berrone, 2018). New management will need to be sustainable using DT as a value driver and human reinforcement advantages, which means to mix it with embracing environmental improvement as a part of an organization or SC's strategy, prioritizing action over words. In this sense, the step from the greenwashing attitude to the brand activism attitude should include the set of efforts made by corporations or cities to promote, impede or direct social, political, economic and environmental reforms with the desire to arise improvements in society (Kotler *et al*., 2018) such as to include the Sustainable Development Goals in their agendas (United Nations, 2019), aiming to more acute deployment of triple bottom line for organizations (Elkington, 2004) identifying the opportunity derived from sustainability as a value drivers for business (United Kingdom Green Building Council, 2018). The technology and DIPVABEM frame can accelerate this mission linked with how to deploy inclusive and rewarding sustainability actions such as the promotion of recycling, reforestation actions, promote the use of non-polluting vehicles, increase the consumption of renewable energy, monitor of waste or actions aimed at better governance reducing transaction costs, deploy more refined tax towards the agents that pollute the most, implement more active marketing plans close to the consumer -educating them by responsible promotions-, accelerate citizen knowledge participation in cities, promote healthier habits of the inhabitants and so on. In summary digital mindset focused on sustainability opens the door that the institutions, corporations and consumers can work together to make tomorrow's cities more human, sustainable, transparent and smart.

In short, DIPVABEM frame managerial implications allows to rethink value for organizations and institutions, advancing the value creation and encouraging the value capture, exchange and distribution. This frame allows to expand the original ideas behind important concepts such as digital value to society (DVS) (Martin *et al*., 2018) and value based management (VBM)

(Haspeslagh *et al*., 2001), including in them more holistic vision, the programmable economy and the "Internet of value" advantages.

7.7.3. Limitations

This thesis has several limitations.

A general limitation is that this thesis focuses much more on developed countries and cities than developing ones. The reason is that the experts' sample belong to the developed countries and therefore their opinion is biased towards developed cities. Regarding the "Internet of value", it has been said that PE advantages would not be deployed until some type of digital installation stage has been achieved, which does not mean that these types of agents in these developing countries or cities can explore potential benefits of the digital in the future. Actually, they need to combine infrastructure investment and regulations as a priority with digital transformation, considering that they have the opportunity to prepare for their future better if they consider everything that DIPVABEM frame means.

As a limitation in Chapter 3, causality factors were not analysed because it has been prioritized the relationship between digital ecosystem and GVA rather than causality using simple methodology such Bayes Theorem, leaving this for future analysis. On the other hand, prioritizing the overall simplicity in the initial approach, in this study, digitalization was investigated in its aspects related to a specific set of official indicators (DESI, GCI, GII) or own elaboration (EENG), and the study did not consider other factors, indices or data in the digital and country economic environment. Furthermore, there was no mention of the business processes or companies' or industries' models or other very important variables, such as the education system, poverty levels, natural resource capabilities, trade opening rates and many others. In addition, the model used does not include the level of sectoral specialization of each country, its "ad hoc" competitive advantages or other factors, such as monetary and tax policies, employment, or foreign direct inflow (FDI), among other GVA impact factors. Another notable limitation is that the index was weighted at the same level for both proxies of the CEI aggregate index because this analysis did not pretend to find the causality or any type of correlation between the variables used. Finally, the study did not include other countries outside the EU28 because homogeneous digital transformation index worldwide there is not available by any official institution, which would provide additional value by having more information and having a broader spectrum of contrast for the confirmation of the starting hypotheses.

As a limitation in Chapters 4, 5 and 6, it should be noted that this research only attempted to test the feasibility of the models in exploratory manner in order to facilitate the deployment phase in the future because last one stage is so expensive. Regarding this, this thesis does not discuss important technologies needed to implement the number of models that have been proposed, such as 5G, artificial intelligence, big data, the machine to machine economy, cryptography or circular economy. Similarly, avoiding excess complexity, this thesis does not include other variables of great relevance and very high impact included in the models, such as legal aspects, taxes, user profiles, government policies, experience curves or tech capabilities, and many more, all of which are truly needed to understand DIPVABEM frame in deep.

On the other hand, the contributions of this study are based on the application of different but limited methodologies, such as conditional probability, as well as forgotten effects and fuzzy logic joint, to some contrasted models, with all of them applied to discover the potential for digital transformation and sustainability approaches. The main reason why these methodological tools were used was based on the point that information availability for many decision processes in countries and cities having been vague or imprecise. Additionally, the opinions of some experts were required, and irremediably, these opinions would have contained a certain degree of subjectivity. For this reason, it has been attempted to avoid binary logic using fuzzy logic developing models with intermediate degrees of belonging. Equally, when probabilistic tools were used, an attempt was made to assign a certain degree of probability to an event conditioned to the occurrence of another.

Furthermore, regarding the application of fuzzy logic systems for congestion or sustainability management, many practical issues and challenges should be addressed. Even with a solid theoretical foundation, the success of a system depends on many factors, such as the quality of the experts' opinions, the system's own credibility and its linkage to management decisions (Shang *et al*., 2013). Expert opinions or business managers have been the main information source for the fuzzy logic system. The number of applications that were shown in this thesis have limited numbers of experts, so a one-time effort for a data and iterative process is needed. Equally, the membership functions has been a critically important input for the fuzzy logic system, and to build it, some approach indices have been used. Thus, data and the sensitivity of the model was primarily in the hands of experts.

Similarly, the comments on inference rules or membership functions might have had material impacts on the results. However, back testing based on experience data, if available, could be used to validate or improve the models. Therefore, the fuzzy logic systems that it has been used must be reviewed and updated constantly (Shang *et al*., 2013).

Finally, as a limitation, in this thesis it has been assumed that, if any type of tool, system or framework are placed in the hands of positivists, then it will be used in a positivist way. This reasoning it has been used because it has been considered that as the sustainability solutions are urgent, the consumers, corporations and governments sustainability conviction are increasingly and if tech solutions are available, then people will use in a correct way. But this is a problem that systemic thinking does not solve, that is, how beings humans use the system (Gibbons, 2010; Nielsen, 2018).

7.7.4. Future Lines of Study

Since the appearance of concepts related to digital (digital transformation, programmable economy), along with others, such as SC, motivation and sustainability, many theoretical and practical advances have been presented. In the literature review, this development is evident with the increasing prominence of articles published on these matters.

The contributions presented in this study demonstrate the potential that exists in digital fields and it potential applications over economy, management and business models related actual issues such sustainability or others digital values potential mentioned before from a more holistic perspective. Regarding the contributions presented in this thesis, it is important to highlight as future areas of research the following.

New extensions could be proposed of existing relationships between the digital momentum concept and the digital ecosystem of a country or city using new perspectives, from quantitative methods or the use of multidimensional approaches that use other variables, such as industry types, GVA by sector, FDI inflow and outflow, digital skills, digital entrepreneurship that examines in better detail the causal relationships between these variables and value added or other productivity index performance and could even extend the geographical limits used beyond the EU28 or extending the study according to countries' development levels.

The sustainable applications that it have been exposed in this thesis, could be extended over particular cases such as developing countries, small, medium or large sized cities. This applications could be analysed discovering the possible advantages and limitations of digital and programmable economy and human reinforcement in this kind of territories when human motivation or environment factors has been changed for cultural, wealth or natural resources reasons. In addition, it could be explored the possibility of applying other methodologies, adding other causes and effects beyond the use of individual economic incentives for citizens such as collaborative ones, include different membership functions, and probe the management of other negative externalities that occur in these spaces such as unhealthy food, tobacco additions, citizens' sedentary habits, water management or poverty issues, all with the proposed methodology in this thesis.

New algorithms could be designed within the Fuzzy Inference System that introduce new variables such as those commented on above into the block fuzzification that could be included in the benefits of the digital and PE application deployment, as well as new rules for the experts in the knowledge base section that would enrich these algorithms for better treatment of urban congestion or urban recycling, opening the possibility exploring other issues that affect the sustainability of cities such as the last mile supply chain tracking or medicines recycling.

New possibilities could be examined by DIPVABEM regarding corporate sustainability marketing campaigns, by allowing digital ecosystem to include customer in it, using PE technology to perform actions for the most customized consumers in a decentralized and transparent manner, accepting the inclusion in its value proposals of actions aimed at alleviating the negative effects on the environment that the packaging of the products have from an integrating point of view, as proposed in the ECOCIPEM, considering that this technology allows the endpoints to be joined to make decisions crossing data. Regarding this, it could be possible to deploy some studies related to cross promotional initiatives between corporations and institutions in order to educate consumer over recycling habits, to promote reforestation campaign using tokens economy or developing some statistical data reports using PE applications related to how many corporations are gradually deploying sustainability in their processes such as 100% recycled packages or zero carbon emission.

A new DIPVABEM extension related to how to push (create) and how to pull (capture, exchange and distribute) value could be explored in areas related to inequality management, trust, privacy and governance in cities or triple bottom line management in organizations, market demand, control and natural resource scarcity management in organizations and corporations.

Finally, it could be evaluated in greater detail questions such as, What kind of effects that digital and PE will generate over agents' behaviour? or, What are the machines and artificial intelligence social consequences when they replace humans decision making? or even explore the potential applications of the autonomous economy in cities, formulating questions such as: Who should have the last decision and about what in cities?, What kind of sustainability issues could be delegate to the artificial intelligence and the machines?, How can it measure the value that digitalization offers and guarantee its distribution among the agents?, and finally, Should the algorithms contain sustainability and ethical principles?, among other.

References

Accenture. *Technology for People: the Era of the Intelligent Enterprise*. *Technology vision 2017* (2017).

Ahvenniemi, H., Huovila, A., Pinto-Seppä, I., and Airaksinen, M. What Are the Differences between Sustainable and Smart Cities? *Cities,* **60**, 234–245 (2017).

Ardichvili, A. Learning and Knowledge Sharing in Virtual Communities of Practice: Motivators, Barriers, and Enablers. *Advances in Developing Human Resources* **10**, 541–554 (2008).

Arroyo-Cañada, FJ. and Gil-Lafuente, J. Multidimensional Positioning of a Set of European Smart Cities. In: Peris-Ortiz M., Bennet D., Pérez-Bustamante Yabar D., (eds) *Sustainable Smart Cities. Innovation, Technology and Knowledge Management.* Springer, Cham, (2017).

Ashford, N. A. and Hall, R. P. *Technology, Globalization, and Sustainable Development: Transforming the Industrial State. 1–720.* Yale University Press, (2011).

Atluri, V., Dietz, M. and Henke, N. Winning in digital ecosystems. Digital McKinsey Insights. Mckinsey (2018). At https://www.mckinsey.com/~/media/McKinsey/Business%20Functions/McKinsey%20Digital/Our%20Insights/Digital%20McKinsey%20Insights%20Number%203/Digital-McKinsey-Insights-Issue-3-revised.ashx (visited on 09/2018).

Bain, J. *Barriers to New Competition. Their Character and Consequences in Manufacturing Industries*. P-123-154. Harvard University Press (1956)

Barnes, C. What's Sustainability Got To Do With It?. Nielsen.com (2018). at https://www.nielsen.com/us/en/insights/reports/2018/whats-sustainability-got-to-do-with-it.html (visited on 09/2018).

Basel, Sound Practices for the Management and Supervision of Operational Risk. *Financial Management Publication*, **62**, 245 (2003).

Batty, M., Axhausen, K.W., Giannotti, F., Pozdnoukhov, A., Bazzanio, A., Wachowicz, M., Ouzounis, G. and Portugali, Y. Smart Cities of the future. *The European Physical Journal Special Topics* 214,481–518 (2012).

Bauman, Z. *Retrotopia*. Paidos, (2017)- pag 103, 1ª Edición.

Belk, R. Extended Self and the Digital World. *Current Opinion in Psychology* **10**,50–54 (2016).

Bell, S., McGeevor, K., Mocca, E. and Shaw, B. Synthesis Report: Review of evidence on the use of reward and recognition schemes in enhancing recycling and waste prevention behaviors (EV0528). Policy Studies Institute. Defra, London (2013).

Belz, F-M. and Peattie, K. *Sustainability Marketing: A Global Perspective*. Chichester: Wiley p-13-28, (2009).

Berenson, M. *Estadistica para Administración y Economía*. McGrawHill, (1992) p-197-203.

Berrone, P. Getting Beyond Greenwashing. Energy and Sustainability. Strategy and Business, (2018) at https://www.strategy-business.com/article/Getting-Beyond-Greenwashing?gko=22d3a (visited on 12/2018).

Bogner, J., Pipatti, R., Hashimoto, S., Diaz, C., Mareckova, K., Diaz, L. and Gregory, R. Mitigation of Global Greenhouse Gas Emissions from Waste: Conclusions and Strategies from the Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report. Working Group III (Mitigation): *Waste Management & Research* **26**, 11-32 (2008).

Bolumar, R. Innovation Edge: Hola Digital. ¿Me vas a convertir en API? Innovation Center BBVA, (March, 2015).

Boucher, P., Nascimento, S. and Kritikos, M. How Blockchain Technology Could Change Our Lives. *European Parliamennt* 4-25 Research Service24 (2017).

Bouton, S., Hannon, E., Haydamous, L., Heid, B., Knupfer, S., Naucler, T., Neuhaus, F., Nijssens, S. and Ramanathan, S. An Integrated Perspective on the Future of Mobility, part 2: Transforming urban delivery. (2017) Mckinsey.com at https://www.mckinsey.com/~/media/mckinsey/business%20functions/sustainability%20and%20resource%20productivity/our%20insights/urban%20commercial%20transport%20and%20the%20future%20of%20mobility/an-integrated-perspective-on-the-future-of-mobility.ashx (visited on 02/2018).

Bouton, S., Knupfer, S. M., Mihov, I. and Swartz, S. Urban Mobility at a Tipping Point. *McKinsey Center for Business and Environment* 1-9 (2015).

Brook, L. Household Waste Behavior in London 2005. Report for the Greater London Authority. Book Lyndhurts, London (2005).

Bruneckiene, J. and Sinkiene, J. Critical Analysis of Approaches to Smart Economy. 8th International Scientific Conference, *Journal of Business and Management 2014*, Vilnius , Lithuania, (May 15-16, 2014).

Brynjolsson, E. and McAfee, A. Research Brief. Race Against the Machine: How the Digital Revolution is Accelerating Innovation, Driving Productivity, and Irreversibly Tansforming Employment and the Economy, The MIT Center for Digital Business (2012).

Bughin, J., Catlin, T., Hirt, M. and Willmott, P. Why Digital Strategy Falls. Mckinsey Quarterly. Executive summary, (January, 2018).

Bukht, R. and Heeks, R. Defining, Conceptualizing and Measuring the Digital Economy. *International Organisations Research Journal* **13,** 143–172 (2018).

Buterin, V. Bootstrapping a Decentralized Autonomous Corporation: Part I. Bitcoin Magazine. (September, 2013) at https://bitcoinmagazine.com/articles/bootstrapping-a-decentralized-autonomous-corporation-part-i-1379644274 (visited on 03/2017).

Canback. Structure, Conduct, Performance, SCP. (2018) Canback.com at https://www.canback.com/news3/scp/ (visited on 02/2018).

Caragliu, A., Del Bo, C., and Nijkamp, P. Smart Cities in Europe. *Journal of Urban Technology*, **18** (2), p-65–82 (2011).

Coase, R. H. *The Nature of the Firm*. Economica 4, p-386–405 (1937).

Cognizant. Being Digital Means Being More Human, Cognizant Digital Works, (2016). at https://www.cognizant.com/whitepapers/being-digital-means-being-more-human-codex2089.pDIPEF (visited on 02/2017).

Cooray, M., Duus, R. and Bundgaard, L. These Three Factors are Critical to the Success of Future Cities. World Economic Forum (2017). at <http://amp.weforum.org/agenda/2017/09/these-three-factors-are-critical-to-the-success-of-future-cities>. (visited on 09/2017).

Corporate Finance Institute. Learn How to Calculate Compound Annual Growth Rate CAGR. Corporate Finance Institute (2017). at https://corporatefinanceinstitute.com/resources/knowledge/finance/what-is-cagr/ (visited on 01/2018).

Corporate Finance Institute. What is he Bayes Theorem? Corporate Finance Institute, (2018), at https://corporatefinanceinstitute.com/resources/knowledge/other/bayes-theorem/ (visited on 02/2018).

Costanza, R. and Daly, H. *Goals, Agenda, and Policy Recommendations for Ecological Economics*. Ecological Economics. R. Costanza (ed) New York, Columbia University Press (1991).

Czech, B. and Daly, H.E. In My Opinion: The Steady State Economy – What It Is, Entails, and Connotes. *Society, The Wildlife Group, Working Economy, Steady State Society, United States Economics, Ecological States, United States, United* **32,** 598–605 (2004)

Chakravorti, B. and Sankar, R.C., *Digital Planet 2017: How Competitiveness and Trust in Digital Economies vary across the World*. *The Fletcher School, Tufts University* 70 (2017).

Dahlman, C., Mealy, S. and Wermelinger, M. Harnessing the Digital Economy for Developing Countries. *OECD Development Centre Working Papers* 1–77 (2016).

Dao, D. Decentralized Sustainability. Beyond the Tragedy of the Commons with Smart Contracts + AI. Medium (2018), at

https://medium.com/@daviddao/decentralized-sustainability-9a53223d3001 (visited on 06/2018).
Davidson, S., De Filippi, P. and Potts, J. Disrupting Governance: The New Institutional Economics of Distributed Ledger Technology. *Electronic Journal* SSRN (2018). doi:10.2139/ssrn.2811995.
Dhingra, M. and Chattopadhyay, S. Advancing Smartness of Traditional Settlements-case Analysis of Indian and Arab Old Cities. *International Journal of Sustainable Built Environment*, **5**(2), p-549–563 (2016).
Diestel, R. *Graph Theory*. Springer (2017) Ed.5, p-92-99
Drucker, P.F. *The Essential Drucker.* Edhasa, (2003), Ed.1, p-44-45.
Eggers, W. and Skowron, J. Forces of Change: Smart Cities. Www2.deloitte.com (2018) at https://www2.deloitte.com/content/dam/insights/us/articles/4421_Forces-of-change-Smart-cities/DI_Forces-of-change-Smart-cities.pDIPEF (visited on 08/2018).
Elkington, J. *The Triple Bottom Line: Does it All Add up?.* Henrique & J. Richardson (2004), p-1-16. London, England: Earthscan
Europapress. "Hamburgo podría convertirse en la primera ciudad alemana que prohíbe circular a los vehículos diésel". Europapress (2018). at http://www.europapress.es/motor/coches-00640/noticia-hamburgo-podria-convertirse-primera-ciudad-alemana-prohibe-circular-vehiculos-diesel-20180521183834.html (visited on 05/2018).
European Commission. Acuerdo de París - Acción por el Clima - European Commission. Acción por el Clima - European Commission (2015). at https://ec.europa.eu/clima/policies/international/negotiations/paris_es (visited on 02/2018).
European Commission. DESI. The Digital Economy and Society Index. European Commission, (2017) at https://ec.europa.eu/digital-single-market/en/desi (visited on 03/2017).
European Commission. Horizon 2020. Smart, Green and Integrated transport. Important notice on the second Horizon 2020 Work Programme129, (2017).
European Parliament. Mapping Smart Cities in the EU. Europarl.europa.eu, (2014). at http://www.europarl.europa.eu/RegData/etudes/etudes/join/2014/507480/IPOL-ITRE_ET(2014)507480_EN.pDIPEF (visited on 05/2017).
Eurostat, European Commission, Database. (October, 2017) http://ec.europa.eu/eurostat/data/database (visited on 02/2018).
Fageda, X. and Flores-Fillol, R. Atascos y Contaminación en las Grandes Ciudades: Análisis y soluciones. *Fedea Policy Papers* (2018).
Fernández, J.M., Collado, M. and Guzmán, S. *Hacia una visión más integrada e inteligente de las ciudades.* (pp 18-23). Madrid. Congresos Ciudades Inteligentes (2015).

Finette, P. Between the Zeros and Ones: Decoding Digitization, Learn What's Behind Digital Disruption and How to Leverage It. Singularity University Conference, (2017).

Fogarty, H. Reid, L. and Sprott, H., International Review of Recycling Policies. *Scottish Government Social Research*, Edinburgh (2008).

Gartner. "Digitization". IT Glossary (2019) at https://www.gartner.com/it-glossary/?s=digitization (visited don 06/2018).

Gartner. Analysts Explore Next Phases of Digital Business. Gartner Symposium/ITxpo, 4-8 in Orlando (October, 2015). at https://www.gartner.com/newsroom/id/3146018 (visited on 01/2018).

Gartner. Digital Glossary Definition. Gartner, 3Q16 Gartner survey (US) (2017).

Gartner. Programmable Economy Has the Potential to Disrupt Every Facet of the Global Economy. Gartner, (2015). Gartner.com at https://www.gartner.com/newsroom/id/3146018 (visited on 01/2018).

Gartner. Search for "Blockchain" - Gartner IT Glossary. Gartner IT Glossary (2018). at https://www.gartner.com/it-glossary/?s=Blockchain (visited on 01/2018).

Gartner. Seize the Digital Ecosystem Opportunity. Insight from the 2017 CIO Agenda Report. Gartner Executive Programs (2017), https://www.gartner.com/imagesrv/cio/pDIPEF/Gartner_CIO_Agenda_2017.pDIPEF (visited on 03/2018).

Gartner. The Reality of Blockchain. Gartner Trends, (2018) at https://www.gartner.com/smarterwithgartner/the-reality-of-blockchain/ (visited on 6/2018).

Gibbons, T. The Limitations of Systems Thinking. TMS Americas, (June, 2010). at https://tms-americas.com/2010/06/the-limitations-of-systems-thinking-reflections-on-our-recent-web-meeting/ (visited on 06/2018).

Giddings, B. Hopwood, B. and O´Brien G., Environment, Economy and Society: Fitting them Together into Sustainable Development. Sustain. John Wiley & Sons, Ltd., **10**(4), p-187-196, (2002).

Gil-Garcia, J. R., Pardo, T.A. and Nam, T. In Smarter as the New Urban Agenda1–19, Springer, Cham, (2016). doi:10.1007/978-3-319-17620-8

Gil-Lafuente, AM. *Incertesa i Bioengineria*. Real Academia de doctors Barcelona (2008).

Gil-Lafuente, A.M., González, F. and Flores, B. Teoría de los efectos olvidados en la incidencia de la actividad económica en la calidad de vida de los habitants y cuantificación de los efectos para un reequilibrio territorial. *Revista de Investigación en Ciencias y Administración,* **10** (19), 105-122 (2015).

Gill, M. and Schadler, T. *Digitize your business strategy. Executive Overview: The digital business transformation playbook*. Forrester, p-173-191 (October, 2017).

Giudice, M. and Straub, D. IT and Entrepreneurism: An On-Again, Off-Again Love Affair or a Marriage? *MIS Quarterly* **35**,iii–vii (2011).
Global Consulting Company. Digital Platform Strategy. Global Consulting Company, (2018) at https://globalconsultingcompany.de/en/digital-platform-strategy (visited on 02/2019).
Global Innovation Index. The Global Innovation Index, November, 2017 at https://www.globalinnovationindex.org/gii-2017-report (visited on 03/2018).
Goleman, D. *Leadership. The Power of Emotional Intelligence*. More Than Sound LLC (2011), Ed.1, p-20-24.
Hahn, J. Cities of tomorrow- Challenges, Visions, Ways Forward. *European Union Regional Policy Journal* 116 (2011). doi:10.2776/41803.
Hannon, E., McKerracher, C., Orlandi, I. and Ramkumar, S. *An Integrated Perspective on the Future of Mobility. McKinsey & Company*68 (2016).
Harder, MK. and Woodard, R. Systematic Studies of Shop and Leisure Voucher Incentives for Household Recycling *Resources, Conservation and Recycling Journal* 51: 732-753 (2007).
Harrison, C. and Donnelly, I. A. A Theory of Smart Cities. in *55th Annual Meeting of the International Society for the Systems Sciences 2011* 521–535 (2011).
Harvard Business Review. How Blockchain Will Accelerate Business Performance and Power the Smart Economy. *Harvard Business Review* (2017). at https://hbr.org/sponsored/2017/10/how-blockchain-will-accelerate-business-performance-and-power-the-smart-economy (visited on 11/2018).
Haspeslagh, P., Noda, T. and Boulos, F. Managing for value. It's not just about the numbers. *Harvard Business Review* **79,** 64–73, 144 (2001).
Henriette, E. and Boughzala, I. The Shape of Digital Transformation: A Systematic Literature Review. *Mediterranean Conference on Information Systems (MCIS) Proceedings*1–13 (2015).
Henriette, E., Feki, M. and Boughzala, I. Digital Transformation Challenges. MCIS 2016 Proceeding. 33. (2016). at https://pDIPEFs.semanticscholar.org/6db2/e3d8294724f845741171586530965ed4c0a3.pDIPEF (visited on 03/2018).
Heyns, G. Companies that Invest in Sustainability Do Better Financially. *Harvard Business Review* 7-9 (2012) at: https://hbr.org/2012/09/sustainable-investing-time-to (visited on 02/2019)
Hüther, M. Digitalisation: An Engine for Structural Change - A Challenge for Economic Policy. *IW policy paper* (2016) at https://www.iwkoeln.de/fileadmin/publikationen/2016/317419/IW_policy_paper_2016_15_Digitalisation.pDIPEF (visited on 03/2018).

INRIX. Los Angeles Tops INRIX Global Congestion Ranking | INRIX. INRIX - INRIX (2017). at http://inrix.com/press-releases/scorecard-2017/ (visited on 05/2018).

Intrator, Y. Autonomous Economy: Coming Sooner than you Think. J.P. Morgan (2018) at https://www.jpmorgan.com/jpmpDIPEF/1320746682093.pDIPEF (visited on 06/2019)

Jacobides, M.G. Designing Digital Ecosystems. Platforms and Ecosystems: Enabling the Digital Economy. WEF (2019) at http://www3.weforum.org/docs/WEF_Digital_Platforms_and_Ecosystems_2019.pDIPEF (visited 04/2019).

Järvensivu, P., Toivanen, T., Vadén, T., Lähde, V., Majava, A. and Eronen, Jussi, T. *Governance of economic transition*. *Global Sustainable Development Report* **126,** 21 (2019).

Jia,H., Mu Wu, Eunhwa Jung, Alice S, and Shyam S.S. Balancing Human Agency and Object Agency: an end-user Interview Study of the Internet of Things. in *UbiComp'12 - Proceedings of the 2012 ACM Conference on Ubiquitous Computing* 1185–1188 (2012).

Jones, J. H. Evaluation Project Risks With Linguistic Variables - *Proceedings of the Fourth Annual International Symposium, National Council on Systems Engineering (NCOSE)*, San Jose, CA, (1994).

Kandaswamy, R. and Furlonger, D. Pay Attention to These 4 Types of Blockchain Business Initiatives. Gartner.com (2018). at https://www.gartner.com/doc/3868969/pay-attention-types-Blockchain-business (visited on 07/2018).

Kandaswamy, R., Furlonger, D. and Stevens, A. Digital Disruption Profile: Blockchain's Radical Promise Spans Business and Society. Gartner.com (2018). at https://www.gartner.com/doc/3855708/digital-disruption-profile-Blockchains-radical (visited on 06/2018).

Kane, G.C., Phillips, N. A. Copulsky J. and Andrus, G., How Digital Leadership Is(n´t) Different. *Mit Sloan Management Review*. (Spring 2019)

Kane, G.C., Phillips. A.N., Copulsky, J. R., Andrus, G. R. *The Technology Fallacy: How People Are the Real Key to Digital Transformation*. Management on the Cutting Edge. *MIT Sloan Management Review.* Ed 1, p-21-32 (2019)

Kaufman, A. and Gil Aluja, J. *Modelos para la investigación de efectos olvidados*. Milladoiro, Ed. p-76. (1988)

Kotler, P. and Sarkar, Ch. The Case for Brand Activism – A Discussion with Philip Kotler and Christian Sarkar. Marketingjournal.org (2018). at http://www.marketingjournal.org/the-case-for-brand-activism-a-discussion-with-philip-kotler-and-christian-sarkar/ (visited on 08/2018).

Knickrehm, M, Berthon, B. and Daugherty, P. Digital Disruption: The Growth Multiplier. Optimizing Digital Investments to Realize Higher Productivity and Growth. *AccentureStrategy* (2016), at https://www.accenture.com/_acnmedia/pDIPEF-14/accenture-strategy-digital-disruption-growth-multiplier-brazil.pDIPEF (visited on 04/2018)

Kruse, K. Employee Engagement: The Wonder Drug for Customer Satisfaction, Forbes (2014), at https://www.forbes.com/sites/kevinkruse/2014/01/07/employee-engagement-the-wonder-drug-for-customer-satisfaction/ - 51f2cac66d46 (visited on 02/2018).

Lambertini, M. Technology Can Help Us Save the Planet. But More than Anything, We Must Learn it Value Nature. WEF, 2018, at https://www.weforum.org/agenda/2018/08/here-s-how-technology-can-help-us-save-the-planet/ (visited on 06/2018).

Lee, J. H., Hancock, M. G., and Hu, M. C. Towards an Effective Framework for Building Smart Cities: Lessons from Seoul and San Francisco. *Technological Forecasting and Social Change* **89**, p-80–99 (2014).

Luginbühl, B. An Explanation For the Rise Of 'Stable Coins' As A Low-Volatility Cryptocurrency. Forbes.com (2018). at https://www.forbes.com/sites/rachelwolfson/2018/03/29/an-explanation-for-the-rise-of-stable-coins-as-a-low-volatility-cryptocurrency/#336c56685700 (visited on 07/2018).

Malone, T. W., Laubacher, R. and Dellarocas, C. Harnessing Crowds: Mapping the Genome of Collective Intelligence. *SSRN Electronic Journal* (2011). doi:10.2139/ssrn.1381502

Mandami, E.H. Application of Fuzzy Logic to Approximate Reasoning Using Linguistic Synthesis. *IEEE Trans. Computers*, **26** (12):1182- 1191, (1977).

Mandami, E.H. and Assilian, S. An Experiment in Linguistic Synthesis with a Fuzzy Logic Controller. *International Journal of Man-Machine Studies* 7(1):1-13, (1975).

Mankiw, N.G. Smart Taxes: An Open Invitation to Join the Pigou Club. *Eastern Economic Journal* **35**,14–23 (2009).

Manning, H. and Bodine, K. *Outside in. The power of putting customers at the center of your business*. Forrester Research. P-73-74 (2016).

Martin, C., Snabe, J. H. and Nanterme, P. Digital Transformation Initiative: Unlocking $100 Trillion for Business and Society from Digital Transformation. *World Economic Forum and Accenture* 1–75 (2018).

Matlab. El Lenguaje del Cálculo Técnico. Es.mathworks.com (2018). at https://es.mathworks.com/products/MATLAB.html. (visited on 10/2018).

McDonald, M. and Rowsell-Jones, A. *The Digital Edge. Exploiting information & technology for business advantage,* Gartner eBooks p- 31-32 (2012).

Meadow, D.H. and Randers, J. *Limits to Growth: The 30-Years Update. Earthscan*(2004).
Merigó-Lindahl, J. *Nuevas Extensiones a los Operadores OWA y su Aplicación en los Métodos de Decisión.* Diposit.ub.edu (2009). at http://diposit.ub.edu/dspace/handle/2445/35378 (visited on 06/2018).
Muth, K.T. Understanding Digital Assets. *MIT Technology Review*, (2019) at https://www.technologyreview.com/s/613071/understanding-digital-assets/ (visited on 05/2019).
Nakamoto, S. Bitcoin: A Peer-to-Peer Electronic Cash System. *Consulted* 1–9 (2008).
Negroponte, N. *Being Digital.* Ediciones B, S.A. (2000) p-21-23 (1995).
Neirotti, P., De Marco, A., Cagliano, A. C., Mangano, G. and Scorrano, F. Current Trends in Smart City Initiatives: Some stylized facts. *Cities* **38**,25–36 (2013).
Neuberger, D. Structure, Conduct and Performance in Banking Markets. *Thünen-Series of Applied Economic Theory* **12,** (1997).
Nielsen. The Evolution of the Sustainability Mindset. Nielsen.com (2018). at https://www.nielsen.com/us/en/insights/reports/2018/the-education-of-the-sustainable-mindset.html?utm_source=sfmc&utm_medium=email&utm_campaign=newswire&utm_term=11-14-2018 (visited on 09/2018).
Nikogosian, J. Why the World Needs Programmable Money. PaymentEye Editorial Team (2019) at https://www.paymenteye.com/2019/01/15/why-the-world-needs-programmable-money/ (visited on 05/2019)
OECD, Determinants of Productivity Growth. Research program, Policy and Regional Growth. Bak, Basel Economics, (2006), at https://www.oecd.org/eco/public-finance/37034021.pDIPEF (visited on 08/2018).
OECD. Gross Value Added. Glossary of Statistical Terms, (2001), at https://stats.oecd.org/glossary/detail.asp?ID=1184 (visited on 11/2017).
OECD. Going Digital: Making the Transformation Work for Growth and Well-Being. *Meeting of the OECD Council at Ministerial Level* 1-33 (2017*)*. OECD, (2017) doi:10.1787/9789264276284-en
OECD. Municipal waste, Generation and Treatment. Stats.oecd.org (2018). at https://stats.oecd.org/Index.aspx?DataSetCode=MUNW# (visited on 03/2018).
Ottawa. Smart City 2.0. City of Ottawa. Planning, Infrastructure and Economic Development. Documents.ottawa.ca (2017). at https://documents.ottawa.ca/sites/documents.ottawa.ca/files/smart_city_strategy_en.pdf (visited on 04/2018).
Papandreou, Andreas A. *Externality and Institutions*. New York: Oxford University Press. p-223-254 (1994).

Pauseback, J. Modelling New Business Models with IOTA – IOTA. IOTA (2018). at https://blog.iota.org/modelling-new-business-models-with-iota-fadd53c6a192 (visited on 08/2018).
Pemberton, H. Understand how Blockchain Will Evolve Until 2030 and Today's Hype Versus Reality. Gartner, 2018, at https://www.gartner.com/smarterwithgartner/the-reality-of-blockchain/ (visited on 02/2018).
Perera, C., Zaslavsky, A., Christen, P. and Georgakopoulos, D. Sensing as a Service Model for Smart Cities Supported by Internet of Things. *Transactions on Emerging Telecommunications Technologies* **25,** 81–93 (2014).
Pérez, C. Publications - Carlota Pérez. Carlotaperez.org (2016). at http://www.carlotaperez.org/pubs?s=tf&l=en&a=technologicalrevolutionsandtechno (visited on 10/2018).
Porter, M. E. Strategy and the Internet. Harvard Business Review **79**, (2001).
Potts, J., Rennie, E. and Goldenfein, J. Blockchains and the Crypto City. *it - Information Technology* **59,** (2017).
Proust, M. *A la busca del tiempo perdido. Por la parte de Swan.* 1ª Ed mayo, 2000, Valdemar p-221.
Rogers, D.L. *The Digital Transformation Playbook, Rethink your Business for the Digital Age.* Columbia Business School Publishing p- 40-51, (2016),
Ross, J. Don´t Confuse Digital with Digitization. MIT, *MIT Sloan Management Review*, (2017).
Rossington, R. What is the Internet of Value and How will Impact Finance?. Finance Monthly, (2018), at https://www.finance-monthly.com/2018/03/what-is-the-internet-of-value-and-how-will-it-impact-finance/ (visited on 09/2018).
Ryan, R. M. and Deci, E. L. Intrinsic and Extrinsic Motivations: Classic Definitions and New Directions. *Contemporary Educational Psychology* **25**, 54–67 (2000).
Rynn, J. *The Economy is an Ecosystem*. Sanders Research Associates, p-75-89 (2007).
Sandner, P. and Wegner, L. A Disruptive Technology for the Next Step of Digitization. (2017) Digitalspirit.dbsystel.de at https://digitalspirit.dbsystel.de/en/a-disruptive-technology-for-the-next-step-of-digitization/ (visited on 09/2018).
Schmuck, P., Schultz, W. P. and Milfont, T. L. Psychology of Sustainable Development. *Electronic Green Journal* (2003).
Schwab, K. The Fourth Industrial Revolution: What it Means and How to Respond. *World Economic Forum* 1–7 (2016).
Senge, P. *The Fifth Discipline. The Art and Practice of the Learning Organization.* Buenos Aires, Granica , p-25-26 (2012).

Shang, K. and Hossen, Z. Applying Fuzzy Logic to Risk Assessment and Decision-Making. Joint Risk Management. *Casualty Actuarial Society* 1–59 (2013).

Shaw, PJ. and Maynard, SJ. The Potential of Financial Incentives to Enhance Householders' Kerbside Recycling Behavior, *Waste Management* **28,** 1732–1741 (2008).

Sheffi, Y. Balancing Green: When to Embrace Sustainability in a Business (And When Not To). Sheffi.mit.edu (2018). at https://sheffi.mit.edu/sites/sheffi.mit.edu/files/2018-04/News%20Article%205.pDIPEF (visited on 07/2018).

Shy, O. *The Economics of Network Industries*. Cambridge, U.K p-76-89 (2001).

Skinner, B. *Science and Human Behavior*. Macmillan, 59–90 (1953). doi:10.1901/jeab.2003.80-345.

Sloan, H. What is the Programmable Economy?. IoT For All (2018). at https://www.iotforall.com/what-is-programmable-economy/ (visited on 09/2018).

Smith, A. *La Riqueza de las Naciones*. Alianza Editorial, , Ed, 1, p-44 (1994).

Solow, R.M. Sustainability: An Economist's Perspective. Economics of the Environment: Selected Readings. R. Dorfman and N.S. Dorfman. New York, W.W. Norton: 179-187 (1993).

Stamford, C. Programmable Economy. SearchCIO, (2016), at https://searchcio.techtarget.com/definition/programmable-economy (visited on 02/2018).

Steers, R, Mowday, R. and Shapiro, D. L. The Future of Work Motivation. Academy of Management Review. *Academy of Management Review* **29,** 379–387 (2004).

Stern, N. *The economics of climate change: The stern review*. *The Economics of Climate Change: The Stern Review* **9780521877251,** 1–692 (Cambridge University Press, 2007).

Stiglitz, J. *Freefall: America, Free Markets and the Sinking of the World Economy*. New York W.W. Norton, p-221 (2010).

Stolterman, E. and Fors, A.C. Information Technology and the Good Life. in *IFIP Advances in Information and Communication Technology* **143,** 687–692 (Springer New York LLC, 2004).

Sumantran, V., Fine, C. and Gonsalvez, D. *Faster, Smarter, Greener*. *The MIT Press* (2018). at https://mitpress.mit.edu/books/faster-smarter-greener (visited on 09/2018).

Szabo, N. Smart Contracts: Building Blocks for Digital Markets. *Extropy Journal of Transhuman Thought* 1–10 (1996). doi:10.1200/JCO.2011.40.6546

Takagi, T. and Sugeno, M. Fuzzy Identification of Systems and Its Applications to Modeling and Control. *IEEE Transactions on Systems, Man and Cybernetics* **SMC-15,** 116–132 (1985)

Tapscott, D. Getting Serious about Blockchain. McKinsey & Company (2017). at https://www.mckinsey.com/industries/high-tech/our-insights/getting-serious-about-Blockchain (visited on 06/2018).

TelefonicaIoT, Adiós a los atascos | Welcome to The IoT World of Telefónica. Iot.telefonica.com (2018). at https://iot.telefonica.com/blog/adios-a-los-atascos-0 (visited on 10/2018).

The World Bank. Blockchain & Distributed Ledger Technology (DLT). World Bank (2018). at https://www.worldbank.org/en/topic/financialsector/brief/blockchain-dlt (visited on 04/2018).

The World Bank. Digital Adoption Index. World Bank (2018). at http://www.worldbank.org/en/publication/wdr2016/Digital-Adoption-Index (visited on 02/2018).

The World Bank. TCdata360: Informal employment (% of total non-agricultural employment). TCdata360 (2017). at https://tcdata360.worldbank.org/indicators/d1ccc31a?country=BRA&indicator=28114&viz=line_chart&years=2001,2015 (visited on 06/2018).

The World Bank. Urban Development. World Bank (2018). at <https://www.worldbank.org/en/topic/urbandevelopment (visited on 03/2018).

Thorp, N. How Society Will Be Transformed by CryptoEconomics. (2015), Medium. https://medium.com/@noahthorp/how-society-will-be-transformed-by-crypto-economicsb02b6765ca8c. United Nations Conf (visited on 10/2018).

TomTom Traffic Index. Tomtom.com (2016). at https://www.tomtom.com/en_gb/trafficindex/ (visited on 05/2018).

Toyama, K. *Geek-Heresky. Rescuing Social Change from the Cult of Technology*. PublicAffairs. p-211 (2015).

Tsvetkova, M., Yasseri, T., Meyer, E., Pickering, JB., Engen, V., Walland, P., Lüders, M., Folstad, A. and Bravos, G. Undertanding Human-Machine Networks: A Cross-Disciplinary Survey. *ACM Computing*, (November 2015).

United Kingdom Green Building Council. Capturing the Value of Sustainability. Identifying the Links between Sustainability and Business Value. UK Green Building Council The Building Centre, London (2018) at https://gbcsa.org.za/wp-content/uploads/2018/05/Capturing-the-Value-of-Sustainability.pdf (visited on 01/2019).

United Nations. Blueprint for Corporate Sustainability Leadership. *UN Global Compact Reports* **2,**49–62 (2014).

United Nations. Glossary of Environment Statistics: Series F, No. 67/Department for Economic and Social Information and Policy Analysis, United Nations, New York, UN, (1997).
United Nations. *Smart Cities and Infrastructure. Report of the Secretary-General Executive. United Nations Conference on Trade and Development* **19,** 1–18 (2016).
United Nations. The Sustainable Development Goals Report 2019. United Nations, New York, UN, (2019) at https://unstats.un.org/sdgs/report/2019/The-Sustainable-Development-Goals-Report-2019.pdf (visited on 06/2019)
United Nations. United Nations Centre for Regional Development (UNCRD). Uncrd.or.jp (2018). at http://www.uncrd.or.jp/index.php?menu=377 (visited on 11/2018).
United Nations Environment Program. *Towards a Green Economy: Pathways to Sustainable Development and Poverty Eradication. A Synthesis for Policy Makers.* Nairobi: UNEP. P52 (2011).
Van Alstyne, M. The Opportunity and Challenge of Platforms. Platforms and Ecosystems: Enabling the Digital Economy. WEF (2019) at http://www3.weforum.org/docs/WEF_Digital_Platforms_and_Ecosystems_2019.pDIPEF (visited 04/2019).
Van Ark, B. *The Productivity Paradox of the New Digital Economy*. International Productivity Monitor p-13-18 (2016),.
Verfürth, E. M. Sustainable Eco-Cities. Smart Cities. Goethe Institute (2018) at https://www.goethe.de/en/kul/ges/21139222.html (visited 05/2019)
Vermesan, O., Friess, P., Guillemin, P., Gusmeroli, S., Sundmaeker, H., Bassi, A. and Pat, D. Internet of Things Strategic Research Roadmap. *Internet of Things Strategic Research Roadmap* 9–52 (2009). doi:http://internet-of-things research.eu/pdf/IoT_Cluster_Strategic_Research_Agenda_2011.pdf
Vivas, C. Blockchain: *La Revolución Industrial de Internet. Aplicaciones transversales de la Blockchain.* Gestión 2000, p-146 (2017).
Wagensberg, J. *Si la Naturaleza es la Respuesta, ¿Cuál era la Pregunta? Y Otros Quinientos Pensamientos Sobre la Incertidumbre*. Metatemas, Tusquets Editores, S.A. 1ª ed p-21 (2002).
Wei, L. T. and Yazdanifard, R. The impact of Positive Reinforcement on Employees' Performance in Organizations. *American Journal of Industrial and Business Management* **04,** 9–12 (2014).
Weill, P. and Woerner, S.L. Thriving in an increasingly Digital Ecosystem. *MIT Sloan Management Review* **56,** 27–34 (2015).
Weiss, L. *Quantitative Studies of Industrial Organization. In Frontiers of Quantitative Economics*. ed. Michael Intriligator, Amsterdam: North Holland Publishing Co., p-211-223 (1971).

Westerman, G., Soule, D.L. and Eswaran, A. Building Digital Ready Culture in Traditional Organization. *MIT Sloan Management Review* (May, 2019).
Wilson, E.O. *The future of Life*. New York, Alfred A. Knopft, p-102-106 (2003).
Winston, A. The World in 2030: Nine Megatrends to Watch | Andrew S. Winston. *MIT Sloan Management Review* (2019). at https://sloanreview.mit.edu/article/the-world-in-2030-nine-megatrends-to watch/?utm_source=newsletter&utm_medium=email&utm_content=Looking%20Forward%20to%202030&utm_campaign=Enews%20GEN%205/14/2019%20Winning%20Version (visited on 04/2019).
World Commission on Environment and Development. Report of the World Commission on Environment and Development: Our Common Future (The Brundtland Report). *Medicine, Conflict and Survival* **4,** 300 (1987).
World Economic Forum. Expanding Participation and Boosting Growth: The Infrastructure Needs of Digital Economy, World Economic Forum, Geneva 8.Www3.weforum.org (2015). at http://www3.weforum.org/docs/WEFUSA_DigitalInfrastructure_Report2015.pDIPEF (visited on 09/2018).
World Economic Forum. TCdata360. WEF Environmental sustainability, 1-7 (best). TCdata360, World Economic Forum, (2018). at https://tcdata360.worldbank.org/indicators/tour.comp.env?country=BRA&indicator=3554&viz=line_chart&years=2015,2017# (visited on 09/2018).
World Economic Forum. The Global Competitive Index 2016, The Global Competitiveness Report 2016–2017, World Economy Forum, (October, 2017) at https://www.weforum.org/reports/the-global-competitiveness-report-2016-2017-1 (visited on 02/2018).
World Economic Forum. The Global Competitiveness Report 2018. The Global Competitiveness Report 2018, World Economic Forum, (2018). at http://reports.weforum.org/global-competitiveness-report-2018/ (visited on 08/2018).
World Economic Forum. Top Ten Urban Innovations. World Economic Forum, (2015). at http://www3.weforum.org/docs/Top_10_Emerging_Urban_Innovations_report_2010_20.10.pDIPEF (visited on 10/2018).
World Health Organization. Urban Transport and Health. Sustainable Transport. A Sourcebook for Policy-Maker in Developing Cities. Who.int (2011). at http://www.who.int/hia/green_economy/giz_transport.pdf (visited on 07/2018).
Xu, R., Lin, X., Dong, Q. and Chen, Y. Constructing Trustworthy and Safe Communities on a Blockchain-Enabled Social Credits System. in ACM

International Conference Proceeding Series449–453. Association for Computing Machinery, (2018). doi:10.1145/3286978.328702

Yuanyuan. C., Limin, J. and Zundong Z. Mandami Model based Adaptive Neural Fuzzy Inference System and its Application, *International Journal of Computational Intelligence* **5**:1, p- 22-29 (2009).

Zadeh, L.A. The Concept of a Linguistic Variable and its application to Approximate Reasoning. *Information Sciences* **8,** 199–249 (1975).

Zanella, A., Bui, N., Castellani, A., Vangelista, L. and Zorzi, M. Internet of Things for Smart Cities. *IEEE Internet of Things Journal* **1**,22–32 (2014).

Zeynep, T. The Good Jobs Strategy. Interview by MIT Sloan School of Management, (May, 2013).

Zhu, K., Dong, S., Xu, S. and Kraemer, K. Innovation Diffusion in Global Contexts: Determinants of post-adoption Digital Transformation of European Companies. *European Journal of Information Systems* **15,**601–616 (2006).

Zielinski, S. New Mobility: The Next Generation of Sustainable Urban Transportation. Naefrontiers.org (2012). at https://www.naefrontiers.org/file.aspx?id=21915 (visited on 09/2018).

Zimmermann, H.J. *Fuzzy Sets, Decision Making, and Expert Systems*. Kluwer Academic Publishers 3 Ed, p-97-103 (1987).

Appendice

Appendix 1

Winner of the Collaboration Grant for the Research Project: 309711 "Study and analysis of opportunities for improvement of services to citizens and businesses so that Smart Cities and / or other public organizations can achieve with the use of Big Data",

Financial Entity: Telefónica S. A and Bosch Gimpera (Universitat de Barcelona) agreement.

Project Director: Lauroba Pérez, Anna
Period: April-December 2018

Publication: Digital Assets Horizon in Smart Cities: Urban Congestion Management by IoT, Blockchain / DLT and Human Reinforcement Article published in "Modelling and Simulation in Management Sciences. MS-18 2018. Advances in Intelligent Systems and Computing", vol 894. Springer, Cham, DOI https://doi.org/10.1007/978-3-030-15413-4_6

Appendix 2

As part of the thesis, "Mind the Gap. Digitalization & Customer Experience", presentation was shown in Second On / Off International Conference in Marketing Decision Making (Universitat de Barcelona and EAE Business School), Barcelona (Spain), October, 2017.

Appendix 3

As part of the thesis the paper was presented: "Beyond Digital Transformation Index Yield. European Digital Flash ", III Congress Economy and Management, Association of Economists of Catalonia, Barcelona (Spain), May, 2018

Appendix 4

As part of the thesis the paper was presented: "Digital Jump in Smart Cities. Congestion Pricing Management by IoT (Internet of Thing) & DLT

(Distributed Ledger Technology) Model. The Association for Modelling and Simulation in Enterprises (AMSE), International Conference on Modelling and Simulation in Engineering, Economics and Management, Girona (Spain), June, 2018.

Appendix 5

As part of the thesis the paper was presented: "Smart City Negative Spill-Over Effects Management by Digital Assets", Third On / Off International Conference in Marketing Decision Making (Universitat de Barcelona and EAE Business School), Barcelona (Spain), November , 2018.

Appendix 6

As part of the thesis, the paper entitled: "Applications of the Digital Economy and Programmable in Smart Cities. The Case of Urban Congestion as a Digital Asset ", was shown in the Fifteenth International Conference on Technology, Knowledge & Society at CosmoCaixa, Barcelona, (Spain), and March 2019.

Appendix 7

Emerging Scholar Award in Congress: 2019 Conference on Technology, Knowledge & Society. The Fifteenth International Conference on Technology, Knowledge & Society will be held at ELISAVA Barcelona School of Design and Engineering in Barcelona (Spain), March 2019

Appendix 8

Personal interview matrix models example used with experts.

Appendix 1

Bosch i Gimpera
UNIVERSITAT DE BARCELONA

CONVOCATÒRIA DE BEQUES DE COL·LABORACIÓ EN PROJECTES DE RECERCA

D'acord amb la base de la convocatòria 03/2018-494, resolta en data 20 de juliol del 2018, s'estén aquesta

CREDENCIAL DE BECARI DE COL·LABORACIÓ EN PROJECTES DE RECERCA

A favor de l'estudiant **Ferran Herraiz Faixo** amb el DNI **37744945J**

La col·laboració començarà en data **16 d'abril del 2018 fins el 31 de juliol del 2018** i tindrà per objecte col·laborar amb el projecte **309711** de la Fundació Bosch i Gimpera, dirigit pel **Dr./Dra. Lauroba Pérez, Anna**, de la Facultat de Empresa de la Universitat de Barcelona.

Periode prorrogat: 01 d'agost del 2018 fins el 21 de desembre del 2018

Barcelona, 20 de juliol del 2018

Bosch i Gimpera
UNIVERSITAT DE BARCELONA

Firmado digitalmente por 77288064Z
M. CARME VERDAGUER (R: G08906653)
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M. Carme Verdaguer i Montanyà
Directora General de la Fundació Bosch i Gimpera

Appendix 2

Universitat de Barcelona — EAE Business School

Second International On-Off Conference in

Marketing Decision Making

Certificado de Ponencia

Este certificado acredita que la ponencia titulada "Mind the gap. Digitalization & customer experience", cuyos autores son:

Ferran Herraiz Faixó

ha sido presentada en el marco de la Second On/Off International Conference in Marketing Decision Making, celebrada en Barcelona el 5 de octubre de 2017, y organizado por la Universitat de Barcelona y EAE Business School.

Barcelona, 5 de octubre de 2017

Dr. Francisco Javier Arroyo Cañada

Presidente del Comité Organizador

Appendix 3

Col·legi d'Economistes de Catalunya
A servei dels professionals de l'economia i de l'empresa

Congrés d'Economia i Empresa de Catalunya
2018

CERTIFICAT DE PARTICIPACIÓ

Joan B. Casas, **degà** del Col·legi d'Economistes de Catalunya i president del Comitè Organitzador del 3r Congrés d'Economia i Empresa de Catalunya, i Andreu Mas-Colell, president del Comitè Científic,

CERTIFIQUEN QUE

Ferran Herraiz Faixó ha presentat una ponència al 3r Congrés d'Economia i Empresa de Catalunya sobre "*Beyond digital transformation index yield European Digital Flash*", i que ha estat acceptada i incorporada a les conclusions del Congrés.

Joan B. Casas
President del Comitè Organitzador

Andreu Mas-Colell
President del Comitè Científic

Appendix 4

Universitat de Girona
Departament d'Empresa

AMSE

International Conference on Modeling and Simulation

MS'2018 GIRONA CONGRESS

Modeling and Simulation in Engineering, Economics and Management

28-29, June 2018, GIRONA (Spain)

CERTIFICATE OF PAPER PRESENTATION

This is to certify that the paper entitled

"Digital Jump in Smart Cities. Congestion Pricing Management by IoT (Internet of Thing) & DLT (Distributed Ledger Technology) Model."

co-authored by:

Ferran Herraiz, Francisco-Javier Arroyo Cañada, Ana-María Lauroba-Pérez and María-Pilar López-Jurado

has been presented at the MS'2018 GIRONA CONGRESS, held in Girona (Spain), on June 28-29, 2018.

Joan Carles Ferrer

Dr. Joan Carles Ferrer
Co-Chair Organizing Committee

Appendix 5

UNIVERSITAT DE BARCELONA — EAE Business School — THE OSTELEA SCHOOL OF TOURISM & HOSPITALITY

Third On/Off International Conference in

Marketing Decision Making

Certificado de Ponencia

Este certificado acredita que la ponencia titulada "Smart City Negative Spill-Over Effects Management by Digital Assets", cuyo autor es:

Herraiz Faixó, Ferran

ha sido presentada en el marco de la Third On/Off International Conference in Marketing Decision Making, celebrada en Barcelona el 7-8 de noviembre de 2018, y organizado por la Universitat de Barcelona, Ostelea School of Tourism & Hospitality y EAE Business School.

Barcelona, 7-8 de noviembre de 2018

Dr. Francisco Javier Arroyo Cañada
Presidente del Comité Organizador

Appendix 6

Technology, Knowledge & Society

CERTIFICATE
OF ATTENDANCE AND PRESENTATION

This certifies that

Ferran Herraiz Faixó

of Universidad de Barcelona, España, attended the Fifteenth International Conference on Technology, Knowledge & Society at CosmoCaixa, Barcelona, Spain, 11-12 March 2019, as in-person participant. Ferran Herraiz Faixó presented the paper "*Aplicaciones de la economía digital y programable en las Smart Cities: El caso de la congestión urbana como activo digital*". We thank them for their valued contribution. The annual conference is an integral component of the Technology, Knowledge & Society Research Network.

Founded in 2005, the Technology, Knowledge & Society Research Network is brought together by a shared interest in the complex and subtle relationships between technology, knowledge and society.

BUILDING RESEARCH NETWORKS

Dr. Phillip Kalantzis-Cope, Chief Social Scientist
Common Ground Research Networks

COMMON GROUND

ELISAVA
Barcelona School of Design and Engineering

Appendix 7


The International Conference on Technology, Knowledge & Society officially recognizes

Ferran Herraiz Faixó

for excellent scholarship and the promise of significant future achievement.
We therefore bestow the

EMERGING SCHOLAR AWARD

with due respect and gratitude.

Dr. Phillip Kalantzis-Cope, Chief Social Scientist
Common Ground Research Networks

Tatiana Pornova, Spanish Language Conference Producer
Common Ground Research Networks

Technology, Knowledge & Society

COMMON GROUND

Appendix 8

Experts Sample Models

Causas/Causas	Incentivos - vehiculos Tasa Congestion	Incentivos + Ciudadanos Descuentos uso Transporte Público TP o VF	Tasa Congestion + Descuentos TP o VF + Token Economy
Incentivos - vehiculos Tasa Congestion			
Incentivos + Ciudadanos Descuentos uso Transporte Público TP o VF			
Tasa Congestion + Descuentos TP o VF + Token Economy			

Causas/Efectos	Reducción Indice Trafico	Mejora productividad (reducción tiempo muerto)	Mejora medioambiente	Mejora salud	Incremeto uso Trasporte público y VF	Incremento recursos economicos locales	Mejora eficiencia Institutiones	Mejora conectividad, network	Incremento participación ciudadana	Capacitatción infraestructura Digital assets
Incentivos - Vehiculos Tasa Congestion										
Incentivos + Ciudadanos Descuentos uso Transporte Público TP o VF										
Tasa Congestion + Descuentos TP o VF + Token Economy										

Efectos/Efectos	Reducción Indice Trafico	Mejora productividad (reducción tiempo muerto)	Mejora medioambiente	Mejora salud	Incremeto uso Trasporte público y VF	Incremento recursos economicos locales	Mejora eficiencia Institutiones	Mejora conectividad, network	Incremento participación ciudadana	Capacitatción infraestructura Digital Assets
Reduccion Indice Trafico										
Mejora productividad (reducción tiempo muerto)										
Mejora medioambiente										
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Incremento participación ciudadana										
Capacitatción infraestructura Digital assets										