Digital cities for development

Connecting real, sustainable, smart and digital cities

Thays Aparecida de Oliveira

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I dedicate this work to my parents, Acácio e Sãozinha, my beloved, Vitor, for all the support and good energy.
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"It is good to have an end to
journey toward; but it is the journey
that matters, in the end."

Ursula L Guin

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make my life lighter.

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My PhD was more than this thesis, it was a life experience!

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Abstract

This thesis addresses on research accomplished and published during the last five years on the state-of-the-art about the development on Smart and Digital Cities. The world population has been increasing and conglomerating mainly in urban centers and, in order to provide better life quality to citizens, new strategies are being taken under the scope of innovation and technology. Among its contributions, this thesis focuses on the connection between technologies and social science, one of its aims is to perceive the way citizens are being inserted into this rapidly transformed environment. Based on operations research techniques, solutions that cover mobility, marketing, governance, privacy, education, citizen's right, among others, are highlighted in the collection of papers presented here. Cutting-edge concepts of information and communication technologies, internet-of-things, blockchain, smart contracts, internet-of-value, optimization, are introduced, explored and extended, contributing for society to move towards sustainable, efficient and transparent use of technology.

Resum

Aquesta tesi aborda les investigacions realitzades i publicades durant els darrers cinc anys sobre l'estat de la tecnologia en el desenvolupament de les ciutats intel·ligents i digitals. La població mundial ha anat augmentant i aglutinant-se principalment als centres urbans i per tal de proporcionar una millor qualitat de vida als ciutadans, s'estan adoptant noves estratègies en l'àmbit de la innovació i la tecnologia. Entre les seves contribucions, aquesta tesi es centra en la connexió entre les tecnologies i les ciències socials. Un dels seus objectius és percebre la manera com s'està inserint els ciutadans en aquest entorn ràpidament transformat. A partir de tècniques d'investigació d'operacions, destaquen solucions que cobreixen la mobilitat, el màrqueting, la governança, la privacitat, l'educació i el dret del ciutadà, entre d'altres, tal i com s'exposa en aquest treball. Es presenten, exploren i amplien conceptes d'avantguarda sobre tecnologies de la informació i la comunicació, internet de les coses, blockchain, contractes intel·ligents, internet de valor i optimització, contribuint a la societat cap a un ús sostenible, eficient i transparent de la tecnologia.

Resumen

Esta tesis aborda la investigación realizada y publicada durante los últimos cinco años sobre el estado del arte sobre el desarollo de las cuidades inteligentes y digitales. La población mundial ha aumentado y se ha conglomerado principalmente en los centros urbanos y, para proporcionar una mejor calidad de vida a los cuidadanos, se están adoptando nuevas estrategias en el ámbito de la innovación y la tecnología. Entre sus contribuiciones, esta tesis se centra en lá conexión entre las tecnologías y las ciencias sociales, uno de sus objetivos es percibir la forma en que los ciudadanos se insertan en este entorno rápidamente transformado. Con base en las técnicas de investigación operativa, las soluciones que cubren movilidad, marketing, gobernanza, privacidad, educación, derechos de los ciudadados, entre otras, se destacan en la colección de documentos presentados aquí. Se introducen, exploran y amplían conceptos innovadores de tecnologías de información y comunicación, internet de las cosas, blockchain, contratos inteligentes, internet de valor, optimización, contribuyendo a la sociedad hacia un uso sostenible, eficiente y transparente de la tecnologia.

摘要

本论文针对过去五年中完成和发表的有关智能城市和数字城市发展的最新研究。世界人口一直在增加并且主要在城市中心聚集，为了向市民提供更好的生活质量，正在创新和技术范围内采取新的战略。在其贡献中，本论文着重于技术与社会科学之间的联系，其目的之一是了解如何将公民插入这种迅速变化的环境中。基于运筹学技术，此处介绍的论文集中着重介绍了涉及流动性，市场营销，治理，隐私，教育，公民权利等方面的解决方案。引入，探索和扩展了信息和通信技术，物联网，区块链，智能合约，价值互联网，优化等前沿概念，为社会朝着可持续，高效和透明地使用技术做出了贡献。

Resumo

Esta tese aborda pesquisas publicadas nos últimos cinco anos e o estado-da-arte sobre o desenvolcimento de Cidades Inteligentes e Digitais. A população mundial tem aumentando e se conglomerado principalmente nos centros urbanos e, para proporcionar uma melhor qualidade de vida aos cidadãos, novas estratégias estão sendo adotadas no âmbito da inovação e da tecnologia. Entre suas contribuções, esta tese foca na conexão entre tecnologia e ciências sociais, um de seus objetivos é perceber a maneira como os cidadãos estão sendo inseridos nesse ambiente de rápida transformação. Com base em técnicas de pesquisa operacional, soluções que abrangem mobilidade, marketing, governança, privacidade, educação, direito do cidadão, entre outros, são destacadas na coleção de artigos aqui apresentados. Conceitos inovadores de tecnologias da informação e comunicação, internet das coisas, blockchain, contratos inteligentes, internet de valor, otimização, são introduzidos, explorados e ampliados, contribuindo para a sociedade avançar no sentido de um uso sustentável, eficiente e transparente da tecnologia.

Preface

> "We are one verse. We are diverse. We are universe. There is a reason they call it galaxy."
>
> Yvonne Cagle

This thesis has been carried out in the Department of Information and Communication Technologies (DTIC) of Universitat Pompeu Fabra (UPF) in Barcelona, Spain, from Oct. 2016 to Jul. 2020. It was supervised by Dr. Helena Ramalhinho and Dr. Miquel Oliver.

This thesis introduces different works that I have been working during my PhD and some years before starting it. The idea to start the studies in Smart City (SC) theme was due to the theme relevance in our transforming world and my interest in understanding it. Since I was in the DTIC, and my background was in Business, why not to merge SC theme with social sciences? In my investigations about SC in 2016, I noticed that the biggest part of scientific publications were in the computer science and engineering. This was a great impetus to bring together the theme of SC and social sciences and reinforce its importance. In this sense, I worked to understand the emerging technologies in cities and how it can connect citizens inside the city.

I started to understand how cities are made and for whom it should be designed, which is to attend the needs of the citizen. The population growth and consequently urban growth, makes the concept of SC to be a goal for improving the quality of life. The use of technologies to follow this growth, and how it is related to citizens, became the aim of this work.

Helena and Miquel supported the idea, we started to discuss it and I talked with professors from different Departments and students about SC theme and discuss what they understand about SC. Helena put me in touch with two responsible for Municipal Data Office Barcelona, part of BCN Tech City, when I had the opportunity to understand how the city data is being used and how the city is divided to facilitate it control. It was possible to realize that cities are currently using different technologies to deal with urban growth and, still, there are some challenges to be faced.

The city is a tangle of technologies that involve different areas inside it, in this sense, through partnerships with researchers and professors from different topics of interest and fields, it was possible to perform multi-disciplinary works that involved different areas that apply technologies within the city. I believe that readers will feel this experience in the collection of articles presented in this thesis.

Another important topic to highlight involves academic events. Tables 1, 2 and 3 summarize the workshops and Special Session (SS) organized during the last years, in which I was actively engaged. In 2017, Helena invited me to be a volunteer in the organization of the 2th edition of the Metaheuristics International Conference in UPF. Helena was one of the conference chairs and it was a learning experience for me to see from behind how a big conference is organized. In the same year, thinking about how interesting it would be working with SC and OR, we founded a cities' focused researching group so-called Creating.City [Creating.City, 2020]. At the moment we started to organize a group of researching, we noticed the general interest of the academic community in engaging in such discussions, as well as the private and the public sector. In the XLIX Brazilian Symposium of Operational Research, we organized our first special session named "Operational Research and Smart Cities". The session was a success, in a conference with more than 500 participants, we had almost 20 papers dedicated to this SS. The papers involved cities' logistic problems, challenges to connect citizens in SC, multimodal transport, routing problem with electric and green vehicles, a simulation of an assistive SC, home energy consumption, among others. The result of this first workshop gave more strength to continue this research. In this symposium, we were invited by Springer Nature to organize a book about SC and Operational Research in the Urban Computing Series. In 2019 the book was launched, entitled "Smart and Digital City: From Computational Intelligence to Applied Social Sciences". It is a collection of articles developed by researchers engaged in the subject. Just after one month of its launch, it had almost 5000 downloads, creating awareness in institutions around the world, reaching researchers, students and professionals. Another important point during my PhD and for my personal growth were the opportunities to share my knowledge in some conferences, meetings and forums, which I highlighted in this table.

TABLE 1 Timeline of events, special sessions, workshops and conferences that contributed with ideas for this thesis, 2016-2017.

2016	**4th International Conference on Variable Neighborhood Search**. Oct. 3-5. Málaga, Spain.I presented the article: "A VNS approach for book marketing campaigns generated with quasi-bicliques probabilities.";
2017	**12th Metaheuristics International Conference**. Jul. 4-7. Universitat Pompeu Fabra, Campus Ciutadella, Barcelona, Spain. I was member of the organization team;
	1st SS: Operational Research & Smart City in **XLIX Brazilian Symposium of Operational Research**, Aug. 27-30, Blumenau/SC, Brazil. I was member of the organization team and attended the conference;
	5th International Conference on Variable Neighborhood Search. Oct. 02-04, Ouro Preto/MG, Brazil. I was chair of the Proceedings and the Organizing Committee;
	1st Workshop on Computational Intelligence and Smart Cities in **XIII Brazilian Congress on Computational Intelligence**. 30 Oct. - 01 Nov. Niterói/RJ, Brazil. I was member of the organization team;
	2nd SS: Computational Intelligence for Smart City in **IEEE Symposium on Computational Intelligence for Engineering Solutions**. Nov. 27 - Dec. 01, Honolulu/Hawai, USA. I was member of the organization team;

TABLE 2 Timeline of events, special sessions, workshops and conferences that contributed with ideas for this thesis, 2018.

2018	**Blockchain Summit Latam**. May 08-09. Santiago/Chile. I assisted the organization of a Blockchain Hands On and attended presentations of the event;
	Southeast Regional Meeting Connected Smart Cities. May 25. Belo Horizonte/MG, Brazil. I attended the meeting;
	2nd Workshop on Computational Intelligence and Smart Cities. in **IEEE World Congress on Computational Intelligence** Jul. 8-13. Rio de Janeiro/RJ, Brazil. I was member of the organization team and presented the article: "Citizens and Information and Communication Technologies".
	She's Tech Conference. Nov. 21-23. Belo Horizonte/MG, Brazil. I attended the conference;
	OuroTech: blockchain, far beyond bitcoin. Nov. 10. Ouro Preto/MG, Brazil. I was member of the organization team and gave a speech entitled "Emerging technologies for smart cities"(In Portuguese);
	Urban Planning, Digital Cities and Intervention with citizens. Nov. 12 and 19. Ouro Preto/MG, Brazil. I gave a 4 hours class in the Urban Engineering course at Universidade Federal de Ouro Preto;
	IxDA: New futures for cities. Nov. 30. Ouro Preto/MG, Brazil I gave a speech entitled "New futures for the cities".

TABLE 3 Timeline of events, special sessions, workshops and conferences that contributed with ideas for this thesis, 2019-2020.

2019	**NEO DevCon**. Feb. 16-17. Seattle/WA, USA. As member of NeoResearch Team I assisted their exposition and attended the conference;
	International Women's Day. Mar. 30, 2019. Google Belo Horizonte/MG, Brazil. I attended the conference;
	NEO Community Assembly. Sep. 06-09 Shanghai/China. As a member of NeoResearch Team I participate in this assembly and reported its discussions;
	Ethereum Devcon. Oct. 08-11. Osaka/Japan. I attended the conference as a Developer/Ecosystem Maker invited by Ethereum DevCon and as a member of NeoResearch Team;
	Manaus Digital Polo Fair (In Portuguese). Oct. 15-17. Manaus/AM, Brazil. I gave a speech entitled "Smart and Digital Cities: From Computational Intelligence to Applied Social Sciences";
	3rd Workshop on High Performance Computing for Smart Cities in **International Symposium on Computer Architecture and High Performance Computing**. Oct 15-18, Campo Grande/MS, Brazil. I was member of the organization team;
2020	Mini-workshop of launch of the Springer Book **Smart and Digital City: From Computational Intelligence to Applied Social Sciences**. Feb. 17, 2020, Universidade Federal Fluminense, Niterói/Brazil. I was member of the organization team.

Contents

List of Tables

Acronyms

CI Computational Intelligence

DC Digital City

DG Digital Government or e-governance

ICT Information and Communication Technologies

IoT Internet-of-Thing

IoV Internet-of-Value

NEO NEO Smart Economy

OR Operations Research

SC Smart City

SS Special Session

TOPDM Targeted Offers Problem in Direct Marketing Campaign

Chapter 1

INTRODUCTION

> "Look at a day when you are supremely satisfied at the end. It's not a day when you lounge around doing nothing, it's when you've had everything to do and you've done it."
>
> Margaret Thatcher

The human population has been growing over the years and more than sixty eight percent of the world's population will live in urban areas by 2050. In 2018, this number was around fifty five percent and since 1890 the human population quadrupled [Cohen, 1995]. In order to attend this high number of citizens in urban centers and high demographic density, an urban planning to provide quality of life for its inhabitants is necessary, mainly dealing with daily services and activities. This implies greater needs for energy, transportation, public building and spaces, infrastructure and services. Those are aligned with the emergence of the Smart City (SC) concept, seeking urban planning and life quality. Historically, the term was introduced in the 1990s [Gibson et al., 1992], initially approaching the relation between cities, technology and opening perspectives on how technology advances can be applied to cities. This concept has been growing and gaining attention from scholars and interests from the public and private sector. The latter, in a search for funds throughout innovation and opportunities to cover cities' growing demands, boosted the connection with devices based on Information and Communication Technologies (ICT), Computational Intelligence (CI), Internet-of-Thing (IoT) and, later, Blockchain. Aligned with the use of such tools, the concept of Digital City (DC) also grew because of the similarities between cities and digital devices, that's why this nomenclature brings technological innovation aligned with what has been highlighted as SC benefits. The concepts of DC

and ICT can walk side by side in order to look for better urban planning and development of the cities [DóAuria et al., 2014] throughout sustainable forms of expansion [Ahvenniemi et al., 2017]. In addition, it has the goal of identifying promising problems that operations research Operations Research (OR) optimization techniques, using techniques such as metaheuristics [Gendreau et al., 2019] and linear integer programming [Jünger et al., 2009], can face in order to assist cities' transformation toward a digital and smart paradigm. The use of ICT has the potential to develop cities' mobility, governance, health care, industry, services, among others. If smartly used, these concepts can even improve citizens participation and engagement into social decisions. In this context, Digital Government or e-governance (DG) [Coe et al., 2001] turns to be an important tool to idealize this connection, strengthening the relations between government and citizens. The DG can promote technologies to connect citizens and cities, and has important key elements such as e-services, e-democracy, e-management. This transformation requires cutting-edge technologies in order to accomplish standards that have been adopted in Europe such as protection of individual privacy [Raschke et al., 2018, Afonso et al., 2015]. Luckily, blockchain technology has arrived to assist in data transparency and reliability, offering trusted networks, despite still being a fresh new concept. Besides that, blockchain promotes tokenization of assets and enables exchange of value on the internet, known as Internet-of-Value (IoV). This is related with a sustainable digital transformation [Barbosa et al., 2019] which should happen in the urban sphere, approaching renewables, blockchain, decentralized technologies and democracy channels. Some technologies might provide a more participative decision-making process, strengthening ties between citizen and government. E-governance is an important tool for delivering government services [Coe et al., 2001] and, together with blockchain technology, it becomes possible to provide transparency, auditable data, using cryptography technologies and networks of trust.

ICT encompasses a set of tools able to transform the technology in a way to adapt and conduct society throughout an informatization process, from public to private solutions. Different kind of technologies can be integrated to proportionate a better quality in everyday life. In this sense, it can improve and integrate citizens' connection in many areas in the city. However, when these technologies emerge, how will citizens relate to them? The study of [Chun et al., 2010] argues that citizens voice must be heard to transform and shape current government policies, acting in a clear and transparent way. Thus, there is a need in moving these concepts towards smart governance and higher citizen participation.

1.1 Objectives

The main goal of this thesis is to contribute with the ability of improving/designing a city, starting from infrastructure to governance, based on a deep understanding of the challenges faced by the citizens. In addition, it has the goal of identifying promising problems that operations research techniques can face in order to assist cities' transformation toward a digital and smart paradigm.

Some specific objectives handled within the collections of papers presented here are:

- Prepare a review of the main approaches of the history and trends of SC and DC concepts, highlighting advantages and disadvantages of ongoing discussions, presenting state-of-the-art studies, open challenges and directions over these topics;
- Identify key elements from ICT, OR and other emerging technologies such as blockchain, on the scope of cities;
- Identify challenges that citizens face when inserted in these emerging ubiquitous technologies;
- Prospect DG tools that can be used to increase citizen's participation and ensure transparency;
- Investigate operations research problems within the scope of the digital transformation being held on cities around the globe, such as:
  - Transportation and mobility;
  - Marketing optimization problem inside the scope of SC, which involves big data to be optimized, privacy to be considered and other features.

For this purpose, some key research questions have been raised:

- Has the concept of smart city been explored to benefit citizens?
- What have been the challenges that cities are facing for improving citizen's life quality?
- Did works from the literature covered citizens' awareness in relation to emerging technologies?
- What are the key problems that ICT, OR and other emerging technologies can be beneficial in short, medium and long-term?

1.2 Methodology

The methodology applied in this thesis started from the studies about smart cities and operations research problems. The theoretical framework is a combination of extensive literature research, including data from public repositories from cities, and mathematical programming techniques based on metaheuristics, such as Iterated Local Search [Lourenço et al., 2003], and discrete-event simulation. All the tools on the scope of the thesis are well-established in the literature and appropriate for the problems at hand. The research carried on also conducted a bibliometrics study to make quantitative findings with experts backgrounds obtained from public research databases between 2016 and 2020 in order to obtain key directions to be explored in this study. The bibliometric research was conducted with different databases in order to understand the relation between SC themes with other areas, like: social sciences, operations research, citizens, IoT, democracy, DG, ICT and blockchain.

The rich set of references that appear in the bibliography comprised in the collection of papers presented here is a evidence of the good amount of background reading and literature review that has been undertaken. In addition, the methodology involved an active and intense participation in academic events, as well as the organization of workshops and pioneers conferences involving the theme of Smart City. By acquiring this experience and being in touch with a variety of researchers, it was possible to connect ideas with brainstorming section and even editing a book. By following these principles, it was allowed to suggest the right set of methods to be identified for the applied problems described in the thesis (some of them with didactic resolutions proposed here, and other ones left open as current challenges). Thus, for reaching our objective, this research is based on arranging a wide background on smart cities and its importance for boosting societal transformation.

1.3 Contributions and thesis structure

The major contributions of this current work are divided in a series of academic papers, which aim in covering the objectives of this thesis. The papers published in conferences and journals are presented as timelines in Tables 1.1 and 1.2. An edited book and book chapters are presented in the Table 1.3.

The core of all forthcoming chapters of this thesis is composed by a selection of papers in which I contributed with different roles: principal writer; data research; statistical analyses; ideas; motivations; co-writer; statistics designer or tester.

Chapter 2 – Cities and Technologies: presents a strategic survey on SCs,

Table 1.1: Published papers in conferences and journals, 2017-2018.

2017	**Oliveira, T.A.**, Coelho, V. N., Ramalhinho, H., Souza, M. J., Coelho, B. N., Rezende, D. C., & Coelho, I. M. (2017). A VNS approach for book marketing campaigns generated with quasi-bicliques probabilities. Electronic Notes in Discrete Mathematics, 58, 15–22. [Oliveira et al., 2017a].
	Coelho, V. N., **Oliveira, T.A.**, Coelho, I. M., Coelho, B. N., Fleming, P. J., Guimarães, F. G., Ramalhinho, H., Souza, M.J., Talbi, E.G. & Lust, T. (2017). Generic Pareto local search metaheuristic for optimization of targeted offers in a bi-objective direct marketing campaign. Computers & Operations Research, 78, 578-587. [Coelho et al., 2017a].
2018	**Oliveira T.**, Coelho V.N., Tavares W., Ramalhinho H., Oliver M. (2017), Operational and digital challenges to connect citizens in smart cities (In Portuguese). In Proceedings of the XLIX Brazilian Symposium of Operational Research (SBPO), Sep 16–19, Blumenau, Brazil. [Oliveira et al., 2017b].
	Coelho, V. N., Veloso, I. F., **Oliveira, T. A.**, & Veloso, I. (2017). A multi-criteria view about judicial and legislative decision making in digital cities and societies (In Portuguese). In Proceedings of the XLIX Brazilian Symposium of Operational Research (SBPO), Sep 16–19, Blumenau, Brazil. [Coelho et al., 2017b].

Table 1.2: Published papers in conferences and journals, 2018-2020.

2018	**T. A. Oliveira**, A. C. Barbosa, H. Ramalhinho and M. Oliver. Citizens and Information and Communication Technologies, 2018 International Joint Conference on Neural Networks (IJCNN), Rio de Janeiro, 2018, pp. 1-7. doi: 10.1109/IJCNN.2018.8489031. [Oliveira et al., 2018].
	A. C. Barbosa, **T. A. Oliveira** and V. N. Coelho, Cryptocurrencies for Smart Territories: an exploratory study, 2018 International Joint Conference on Neural Networks (IJCNN), Rio de Janeiro, 2018, pp. 1-8. doi: 10.1109/IJCNN.2018.8489299. [Barbosa et al., 2018].
2020	**Oliveira, T.A.**; Gabrich, Y.B.; Ramalhinho, H.; Oliver, M.; W. Cohen, M.; S. Ochi, L.; Gueye, S.; Protti, F.; A. Pinto, A.; V. M. Ferreira, D.; M. Coelho, I.; N. Coelho, V. Mobility, Citizens, Innovation and Technology in Digital and Smart Cities. Future Internet 2020, 12, 22. [Oliveira et al., 2020a].
	Oliveira, T.A.; H. Ramalhinho and M. Oliver. Challenges for connecting citizens and smart cities: ICT, e-governance and blockchain. Sustainability 2020, 12, 2926. [Oliveira et al., 2020b].

Table 1.3: Book and book chapters, 2019.

2019	Coelho, V. N.; Coelho, I. M.; **Oliveira, T. A.**; Ochi, L. S.. Smart and Digital Cities: From Computational Intelligence to Applied Social Sciences. Urban Computing. 1ed.: Springer International Publishing, 2019, v. 1, doi:10.1007/978-3-030-12255-3. [Coelho et al., 2019b].
	Coelho, V. N.; Coelho, I. M.; **Oliveira, T. A.**; Ochi, L. S.. Introduction. Urban Computing. 1ed.: Springer International Publishing, 2019, v. 1, p. 1-, doi:10.1007/978-3-030-12255-3_1. [Coelho et al., 2019a].
	Oliveira, T.A., Coelho, V.N., Ramalhinho, H., Oliver, M. (2018). Digital Cities and Emerging Technologies. Urban Computing. 1ed.: Springer International Publishing, 2019, v. 1, p. 197-207. [Oliveira et al., 2019].
	Coelho, V. N., Gabrich, Y. B., **Oliveira, T. A.**, Ochi, L. S., Barbosa, A. C., & Coelho, I. M. (2019). When CI and Decentralized Systems Effectively Meet Smart Cities and Grids. Urban Computing. 1ed.: Springer International Publishing, 2019, v. 1, p. 239-249, doi: 10.1007/978-3-030-12255-3_15. [Coelho et al., 2019c].
	Coelho, V. N., **Oliveira, T. A.**, Figueiredo, Iara V. O., Souza, Marcone J. F., Veloso, Iuri. A multi-criteria view about judicial and legislative decision making in digital cities and societies. Urban Computing. 1ed.: Springer International Publishing, 2019, v. 1, p. 209–220, doi: 10.1007/978-3-030-12255-3_13. [Coelho et al., 2019d].

searching for challenges for connecting citizens to the emerging infrastructure. This chapter is composed of one journal paper ([Oliveira et al., 2020b]), three papers presented and published on conferences, namely ([Oliveira et al., 2018] [Barbosa et al., 2018] and one, in Portuguese [Oliveira et al., 2017b], presented in the appendix) and one book chapter ([Oliveira et al., 2019]). These works contributes with an updated view on cities challenges throughout up-to-date bibliometrics and discussions on emerging technologies.

Chapter 3 – Smart Cities and Operations Research: has its main focus on operations research inspired techniques, which are contributions focused on distinct cities' services such as mobility, energy, optimization of social participation throughout multi-criteria decision making process. It is composed of one journal paper ([Oliveira et al., 2020a]), one conference paper (appendix in Portuguese [Coelho et al., 2017b]) and two book chapters ([Coelho et al., 2019d]) ([Coelho et al., 2019c]).

Chapter 4 – Digital Marketing: contributes with a vision about direction marking in modern cities and society. An optimization problem is dealt in order to focus on improving direct marketing campaigns, which can be applied for efficient offer of services on smart cities. It also consider those campaigns managed with a Smart Contract tested on the NEO Blockchain, as well as the design for automatic campaigns throughout decentralized protocols.

This chapter is composed of two journal papers ([Coelho et al., 2017a] and [Oliveira et al., 2017a]), as well as one paper under revision (in Appendix A.1).

Chapter 5 – Final Remarks: draws final considerations and points out future directions.

Appendix A.1 – Additional Contributions: includes extra papers which are under review or were already published in other languages such as Portuguese.

Chapter 2

CITIES AND TECHNOLOGIES

> "I was taught that the way of progress was neither swift nor easy."
>
> Marie Curie

This chapter presents a deep state-of-the-art analysis about SC as well as its trends on citizens relationship with smart and digital cities. It is the first one to be presented in order to show the interdisciplinary of this topic and its relation with other technologies such as DG, ICT, cryptocurrencies and blockchain, approaching the use of emerging technologies inside the scope of SC. It brings interesting discussions involving open points to be explored by considering social decisions conducted and undertaken by citizens. The contribution is centered in an overview of the evolution, challenges and tendencies for the future SC, presenting the theme of e-governance and its contribution for and effective integration between cities and citizens, together with the potential use of IoT devices embedded with ICT capabilities, blockchain and other emerging technologies.

Some contributions in this Chapter, are:

- Challenges surrounding citizens' participation in the city;
- Highlight the multidisciplinarity involved in the theme and the various areas combined on it;
- Present relevant discussions and state-of-the-art surrounding smart and digital city theme ans its evolution;
- Present the SC objectives in a city: planning, construction and the infrastructure of intelligent services offered to citizens, which are sometimes ubiquitous;

- Present city and citizens integration thought emerging technologies, as ICT and e-governance;
- Discuss about government and citizens' integration, throughout decentralized technologies, as blockchain;
- Blockchain as a tool for promoting trust, lower costs, transparency and exchange of value on services used by citizens.

Papers included in this chapter:

- **Oliveira, T.A.**; H. Ramalhinho and M. Oliver. Challenges for connecting citizens and smart cities: ICT, e-governance and blockchain. Sustainability 2020, 12, 2926. [Oliveira et al., 2020b];
- **Oliveira, T.A.**, Coelho, V.N., Ramalhinho, H., Oliver, M. (2018). Digital Cities and Emerging Technologies. Urban Computing. 1ed.: Springer International Publishing, 2019, v. 1, p. 197-207. [Oliveira et al., 2019]
- **T. A. Oliveira**, A. C. Barbosa, H. Ramalhinho and M. Oliver. Citizens and Information and Communication Technologies, 2018 International Joint Conference on Neural Networks (IJCNN), Rio de Janeiro, 2018, pp. 1-7. doi: 10.1109/IJCNN.2018.8489031. [Oliveira et al., 2018]
- A. C. Barbosa, **T. A. Oliveira** and V. N. Coelho, Cryptocurrencies for Smart Territories: an exploratory study, 2018 International Joint Conference on Neural Networks (IJCNN), Rio de Janeiro, 2018, pp. 1-8. doi: 10.1109/IJCNN.2018.8489299. [Barbosa et al., 2018]

Appendix A.1:

- **Oliveira T.**, Coelho V.N., Tavares W., Ramalhinho H., Oliver M. (2017), Operational and digital challenges to connect citizens in smart cities (In Portuguese). In Proceedings of XLIX Brazilian Symposium of Operational Research (SBPO), Sept 16–19, Blumenau, Brazil. [Oliveira et al., 2017b];

Oliveira, T.A.; Oliver, M.; Ramalhinho, H. Challenges for Connecting Citizens and Smart Cities: ICT, E-Governance and Blockchain. Sustainability 2020, 12, 2926.

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Article

Challenges for Connecting Citizens and Smart Cities: ICT, E-Governance and Blockchain

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Abstract: The way citizens interact with cities affects overall life quality. Their participation in social decisions is of paramount importance for helping on public decisions that affect governance, regulation and education. This interaction has the potential of being boosted within the scope of smart and digital cities, especially by recent advances in blockchain technology. This work introduces insights about how smart cities' concepts and innovative technologies can help society to face daily challenges for improving citizens' awareness. Digital technologies are able to drive social and economic development by employing Information and Communication Technology (ICT) to promote innovation. In this context, e-governance, in conjunction with disruptive concepts such as blockchain, is showing up as a fundamental tool for a decentralized democracy. This study reviews, discusses, raises open points and presents suggestions towards an efficient, transparent and sustainable use of technology, applied to future cities.

Keywords: smart cities; digital cities; citizens; blockchain; ICT; e-governance; sustainability; urban planning; green technologies; smart contracts

Key Contribution: Highlights the state of the art and trends in citizens relationship with smart and digital cities. This study presents an overview of the evolution of the term smart cities, connecting it with the use of ICT and the potential brought by blockchain and other emerging technologies.

1. Introduction

The population has been increasing around the world and, along with this growth, new strategies are being planned to provide a better life for humankind. New initiatives and novel technologies are emerging in various manners, promoting a new wave of innovation within cities' services. However, even with continuous advance of cities and digital technologies, different challenges to engage citizens in social decisions are still open and need to be faced [1]. Information and Communication Technology (ICT) has the potential to improve this relationship with the transformation of cities' systems into decentralized and didactic tools [2]. In this context, e-governance emerges as a fundamental tool and as the first step of this transformation [3].

The concept "Smart City" (SC) was introduced in the 1990s, opening perspectives on how recent technology could affect cities. Dameri and Cocchia (2013) [4] presented an overview on the history of the label "smart", pointing out that the first study that conceptualized SC was in 1992 by Gibson et al. [5], entitled *The Technopolis Phenomenon: Smart Cities, Fast Systems, Global Networks*. Next, SC in connection with ICT and urban evolution started to walk side by side, as can be verified in the works of Graham (1996) [6] and Graham and Marvin (1997) [7]. It can be affirmed that the SC concept is 20 years old and it is in continuous progress [8]. The SC main objective would be

to facilitate the planning, construction and intelligent services of the cities; however, it has been highlighted [4,9–12] that this concept may be becoming so skeptical and futuristic that is being called "smart utopia" [8]. The work of Barbosa et al. (2019) [13] highlights a path for sustainable digital transformation, pointing out some of these concepts and several complexities introduced when modern technologies are in the urban sphere. Sadin (2013) [14] commented on the drawbacks from the accumulation of power of those who manage a high volume of data, which would be the case of smart cities. However, as we emphasize within this study, blockchain and decentralized technologies, such as the use of renewables, enlighten the path for decision making distribution throughout classical means of democracy. In essence, SCs should provide a new view about cities, emphasizing the citizens, which are the most important part of it. Following this reasoning, one of the main goals of these cities should be to make the urban environment more integrated with citizens. More than that, SCs should provide more participative decision-making processes, more sensible and with transparency, inside and outside the government. When we mention transparency, it is worth noting the book of Byung-Chul Han (2015) [15], known as "Society of Transparency", which highlights the difference between trust and exposure. While trust is a quality that is the core of human relationships, transparency has some dual interpretations. Transparency may be becoming a need that extrapolates the trust of the involved stakeholders. Following this reasoning, we carefully point out blockchain as a path of trust and not only a path of transparency. While transparency is not the focus, the main goal is to create networks of trust, in which exchange of information and assets are done in optional transparent manners.

E-governance encompasses how to govern, serve, organize and formulate proposals related to worldwide communities that are settled on urban areas. It works in order to develop technologies to promote citizens' participation in different areas, which has been getting attention in the last decade [16] due to its impact on life quality [17]. This concept also intersects with Civic Tech [18]. Aligned with this, blockchain technology has also recently emerged as a fundamental platform for providing trust and auditable data, through a decentralized peer-to-peer network using cryptographic techniques [19]. It provides the users capabilities of performing decentralized exchange of values/assets in trusted networks, giving birth to the Internet of Value (IoV) [20]. We believe that this is still a rather new concept, with many implications on the next generation protocols and uses by citizens [21].

Some technologies can help to connect smart cities' citizens with city services and tools. As an example of key areas we could highlight: Transportation (smart mobility), politics, governance, education, public transparency and citizens' rights, among others. Infrastructure provides citizens the ability of free choice over the best way to come and go. In another possible view, as briefly mentioned by the European Union Agency for Network and Information Security [22], "Smart Cities rely on an ICT architecture to retrieve, process and exchange data (p. 06)". They mention data exchange because there are different kinds of cities and management policies; however, common data can be used within them. All these areas and concepts work much better when connected, interconnected and promoting participative actions. These are relevant issues for both developed and underdeveloped countries [23]. Technology comes as a tool to facilitate these points with the government.

The research questions focused on in this study are:

- What are the challenges that cities have been facing for improving citizens' life quality?
- Has the smart city concept been explored in order to understand how it can benefit citizens?
- Did works from the literature cover awareness of citizens in relation to emerging technologies?

In order to achieve the desired goal proposed within the scope of this paper, emerging technologies that benefit citizens over the ongoing societal transformation process will be discussed in this study. Based on state-of-the-art available tools and promising ideas, this work focuses on presenting innovative views and trends. The proposed methodology of this research is based on:

- Providing a decent background to smart cities and their importance for boosting societal transformation:

  - Authors being motivated by the innovation brought with the SC concept, which has been motivating governmental discussions, conferences, forums and different incentives for the industry;
  - Thus, this paper highlights an overview of its history and trends.
- Conducting a bibliometrics study in order to identify gaps and trends;
- Connecting the numerical findings with authors' backgrounds obtained from conferences, workshops, roundtables and special sessions organized between 2016 and 2020 [24] in order to obtain key directions to be explored in this study;
- Explore the obtained topics and propose cutting edge solutions using those main keywords selected by the authors (which are ICT, e-governance and blockchain).

In summary, some of the contributions of this work are:

- Present an overview and trends on smart cities;
- Discuss some challenges regarding the relationship of citizens and cities;
- Discuss governance and its contributions for an effective citizens' integration; in particular, throughout decentralized technologies such as blockchain;
- Introduce possibilities, emerging governance models and possible problems that can still be solved.

The remainder of this paper is organized as follows. Section 2 presents an overview of smart cities and academic motivation to investigate this concept. Based on studies from the literature and data obtained from bibliometrics, the authors identified key points to approach technology and citizens, which are introduced in Section 3. That section presents the role of ICT in solving cities' challenges, including discussions about emerging technologies such as blockchain and other trends for innovation and e-governance. Finally, Section 4 concludes the work.

2. Understanding Smart Cities' Importance

Along with fast urban growth comes new confrontations, so cities' transformation plays a fundamental role in facing new barriers, resolving urban problems and improving life quality [25]. Sassen (2004) [26] use the global city term to refer to cities as an important point of financial and producer services that makes the globalized economy run. According to Sun et al. (2016) [27], the world's population will double by 2050. This fortifies and motivates SC studies around the world in order to create more comfortable and harmonious urban spaces. The potential for motivating cities' transformation and novel initiatives is noble since this topic urges discussions from different spheres. In order to define the terms smart city and sustainable city, Ahvenniemi et al. (2010) [12] used 16 city assessment frameworks, eight for each term. A total of 958 indicators were divided by three impact categories (economic, social and environmental) and 12 sectors. They defined that: "Sustainability assessment should be part of the SC development and therefore we find it important to integrate sustainability and smart city frameworks, so that both views are accounted for in performance measurement systems" [12]. Finally, it was recommended to use the term "smart sustainable cities" instead of "smart cities", indicating that metrics for assessment of a smart city should also consider environmental, economic and social sustainability aspects. Yao et al. (2008) [28] advocate that smart cities are more ecologically efficient, with a significant positive and increasing impact over time.

Some of the global standard organizations have been dealing with the smart cities concept such as the International Standards Organization; British Standards Institute; International Telecommunications Union; International Electronical Commission and the American National Standards Organizations. According to these standards, SC is a new concept and city model that involves a new generation of ICT and Internet of Things (IoT), defining it (p. 02) [29] as follows:

> "Smart Cities: a new concept and new model, which applies the new generation of information and communication technologies such as the Internet of things, cloud computing,

> big data and space/geographical information integration, to facilitate the planning, construction, management and smart services of cities."

In 1998, Bollier [30] proposed new political practices to improve urban planning [31] and used the smart growth term. This reaffirms that the SC concept originated from different ideas and scenarios. Dameri and Cocchia (2013) [4] defended SC as the search for solutions for cyber–physical integration in urban space, with the main objective to promote sustainable development of the cities; the SC tend to open new innovations possibilities in diversified areas, like health, welfare, energetic efficiency and transport [27,32]. Zhuadar et al. (2017) [33] conducted a study focused on the next wave of innovation, which combines humans' ability to connect to machines. The studied example is from the IBM Intelligent Operation Center, a so-called "system of systems", which was advocated to improve life quality by integrating data to cities' authorities. The authors concluded that the innovation came from humans' ability to connect to machines and the data obtained from these connections. Modern cities have a great potential to interact between each other in a smooth manner [34,35]. The old empires and former countries of our modern world have always been passing through changes; nowadays, with the recent globalization of communication, we are able to ponder citizens' perspectives [36,37]. Recently, in 2020, Chamoso et al. [38] highlighted that the design and development of platforms for big data processing should be a priority, with focus on citizen-oriented management. As described by Batty (2013):

> "I describe how the growth of big data is shifting the emphasis from longer term strategic planning to short-term thinking about how cities function and can be managed, although with the possibility that over much longer periods of time, this kind of big data will become a source for information about every time horizon." [39] (p. 274).

One of the main motivations for conducting this study is due to the SC relevant concepts and actual focus that it has been receiving by the government and the industrial sector. In an effort to emphasize the wide spread adoption of these concepts, Figure 1 shows the trends from searching the term "smart city" in different languages, with data obtained from Google Trends (which process around 30 million searches per week [39]), a tool that allows the use of data from 2004 and is commonly used to evaluate the popularity of certain keywords.

Interesting patterns can be seen in each of these graphs. Such trends can be related to distinct factors, such as specific funding schemes and policies. For instance, a growing trend on the topic can be seen with searches done in English and Korean, as well as Russian. Portuguese speaking countries have been also showing an upwards tendency. The search with Chinese terms has peaks spread during the period, which provides a clue that there are hypes and cycles in which the topic attracts more interest. The tendency with searchers in French is stable, which emphasizes that the topic has been viewed and researched constantly. For Arabic and Polish, the conclusions are less relevant; however, there can be noticed a growing interest right now (from 11/2019 to 02/2020) with searchers in Polish.

Figure 2 was elaborated in order to illustrate some of these topics and areas possibly covered by a SC, representing its advantages for the citizens. As it is possible to see that the citizens are located in the center circle; this is to represent how important they are in consideration with the services offered to them. The second circle represents items commonly considered in different areas in an SC. These items items can be generalized for all these four exemplified covered areas. The last part composed by the smaller circles exemplifies applications and possible technologies for each area, connecting them with the potential brought by emerging technologies. Following this reasoning, the main idea is to connect different operations and services in favor of improving citizens' lives, in particular, by improving these major cities' strategic fields.

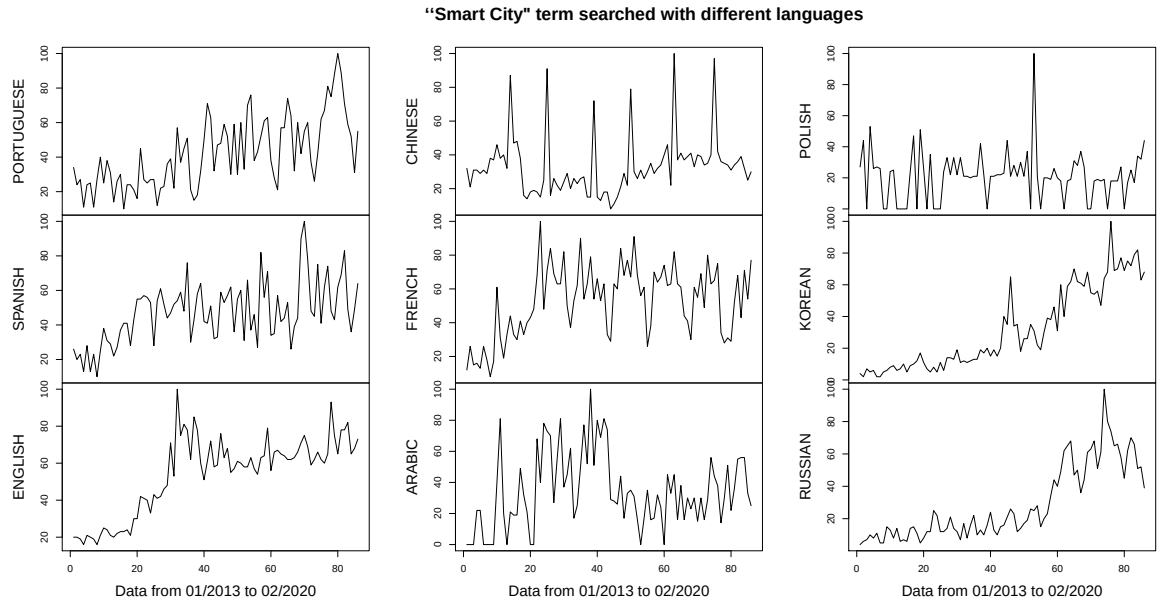


Figure 1. Google Trends search with the term "smart city" in different languages.

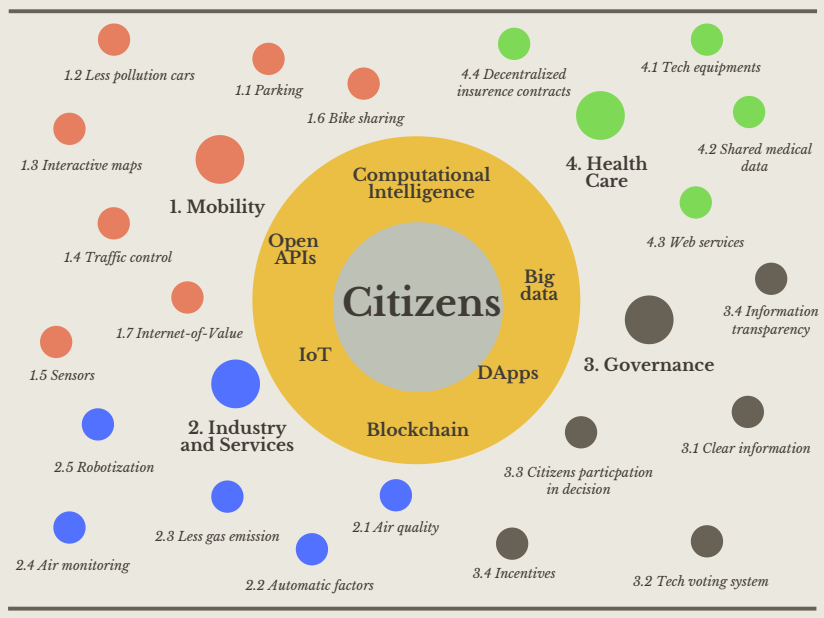


Figure 2. Some areas of expertise and topics covered in the scope of smart cities. Blockchain can be seen as a potential trend.

The success of SC is linked to the connection between strategic areas, as can be verified in the bibliometric search that was conducted. During the organization of workshops, conferences and round-tables surrounding the topic of digital and smart cities, the authors conducted brainstorming sessions for selecting keywords to be investigated (some of them were considered in sets). In this sense, any combination of at least one term in the set with smart city (or smart cities) was considered. The procedure was conducted using generic logic expressions, which were inserted into different global reference databases: Web of Science [40], SCOPUS [41] and IEEEXplore [42]. The following sets of keywords were searched:

1. Smart city or smart cities (namely SC, for simplicity);
2. SC + (Operations Research or Operational Research);
3. SC + Citizens;
4. SC + (IoT or Internet of Things);
5. SC + (E-Governance or e-government or Digital Governance or cybergovernment or cyber government or cyber-government);
6. SC + Democracy;
7. SC + (Social Participation or Social Science);
8. SC + (ICT or Information and Communication Technologies).
9. SC + Blockchain.

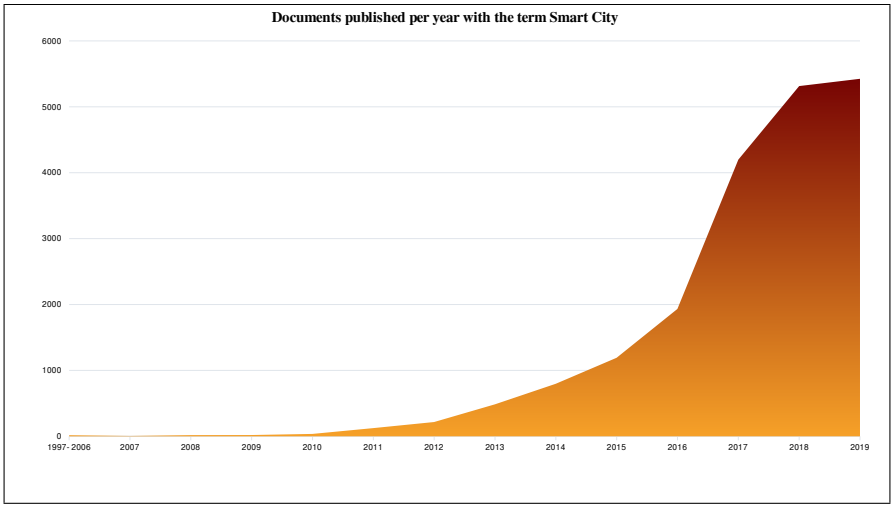
Table 1 presents a summary of the results obtained from searchers on the number of publications for each of the aforementioned keywords, with data from 2016 to 2019. The search was limited to a query on: Keywords, title and abstract. Topics related to operations research and SC were mostly found on IEEEXplore; perhaps this is because they are a more technically focused publisher. As it can be noticed, blockchain is a notorious emerging topic, with less than 100 publications per publisher until 2018.

Table 1. Keywords searched in three different reference databases.

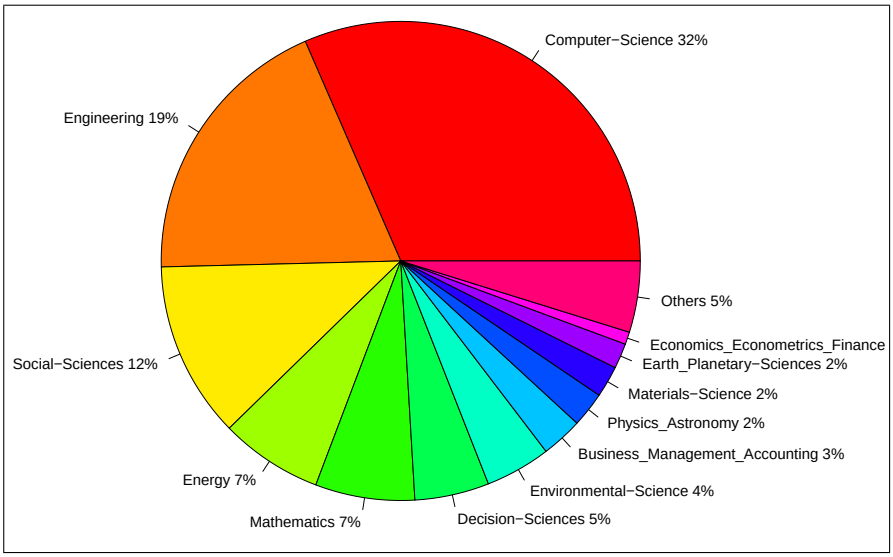
	Keywords								
	[1]	**[2]**	**[3]**	**[4]**	**[5]**	**[6]**	**[7]**	**[8]**	**[9]**
	2016								
Web of Science	2073	44	289	436	41	6	55	213	2
SCOPUS	2466	54	356	465	20	11	92	201	3
IEEEXplore	1772	1178	153	399	19	2	101	381	3
	2017								
Web of Science	2913	60	389	721	57	16	65	302	10
SCOPUS	4750	100	472	829	31	15	132	292	22
IEEEXplore	2038	1199	533	688	17	11	111	487	10
	2018								
Web of Science	3034	66	361	920	69	14	65	312	47
SCOPUS	6092	124	568	1454	46	13	145	396	99
IEEEXplore	3227	2259	191	1051	27	4	142	519	89
	2019								
Web of Science	2603	44	325	767	75	14	71	262	66
SCOPUS	6418	121	604	1524	31	18	121	465	189
IEEEXplore	2333	1547	157	917	24	4	127	532	110

Figure 3a, created with data from SCOPUS database [41], represents the evolution of publications in the theme "smart city", with absolute values by year; the total number is 20,513 by published documents. The starting year of this search was chosen from the time when the first idea that refers to SC appeared, around 1997. The first values represent the sum from 1997 to 2006, since the number of published documents is minimal. Any findings, including the term in the title, abstract or keywords (both the singular and plural), were considered. Figure 3b contains a pie chart showing the percentage of published documents by subject area, with a total sum of 52,336 publications (some documents fall within more than one subject area). It is possible to verify that computer science (16,500) and engineering (9877) comprise the largest portion of publications in SC topics from 1997 to 2019. In this chart, "others" represents the following areas: Chemistry (686); medicine (387); arts and humanities (360); biochemistry, genetics and molecular biology (344); chemical engineering (186); agricultural and biological sciences (149); psychology (122); health professions (90); multidisciplinary

(67); pharmacology, toxicology and pharmaceutics (59); neuroscience (28); nursing (15); veterinary (9); immunology and microbiology (8); dentistry (3); and undefined (3).



(**a**) Evolution of the term "smart city" in published papers, from 1997 to 2019, in the SCOPUS database.



(**b**) "smart city" by published areas.

Figure 3. Data obtained from SCOPUS database with the term "smart city" from 1997 to 2019.

Social science represents the third biggest portion among the published document (according to the data provided in Figure 3b); in this sense, we highlight the importance of connecting SC with other areas. Citizens and local government [43] represent an important relationship to be highlighted and reinforced. Thus, to think of a city adapted to the citizen, in a way to facilitate other services beyond mobility, is necessary. In this context, it is extremely important to brainstorm models about how the citizens can effectively participate in cities' decisions in a democratic and simple way. Section 3.4 presents e-governance, a paradigm with potential for guiding these aforementioned steps.

3. ICT and Emerging Technologies for Cities and Citizens

Emerging technologies and SC models/paradigm are bringing a new wave of decentralized approaches, both in terms of resource allocation, governance models and opportunities for innovation. Section 3.1 introduces blockchain and its use in the context of smart cities. Section 3.2 presents some

challenges for promoting more interactive infrastructure. Section 3.3 promotes the use of technologies that facilitate tourism and encourage visitors to explore a city. Section 3.4 introduces concepts of decentralized governance in the context of digital cities and the possibilities that systems such as blockchain are creating. Section 3.5 discusses how privacy may affect citizens' experience and points out benefits in embedding privacy in products and services. Section 3.6 shows how the motto of smart cities can boost innovation and provide possibilities for novel initiatives.

3.1. Blockchain and Smart Cities

Blockchain based technologies, also known as "distributed ledgers" techniques [44–47], encompass a family of applications that focus on enhancing trust between parties. They have been gaining attention since the appearance of Bitcoin cryptocurrency [19] and also have the potential to reduce costs [48,49].

While many private applications are already running on blockchain, public use of its concepts is just starting to appear, focusing on different aspects of the relationship between entities of the government, citizens, entrepreneurs and industries. For example, in Brazil, the BNDES (National Bank of Development) has been designing a smart contract for management of public funds when bidding happens [50]. Another use case in Brazil involves medical records with transparency, privacy, agility and low cost. Moreover, its use for emission, tracking and verification of official certificates/diplomas has been the focus of some Brazilian entities and also Spanish initiatives [51].

Blockchain can intrinsically promote transparency [52] when correctly used. The first applications were basically on the financial sector and, nowadays, are covering other vertical markets that want to integrate it for different asset management. In the context of SC, few applications can still be found. The work of Aggarwal et al. (2019) [53] introduces the use of blockchain in decentralized architecture between different geo-located IoT nodes in an "increasingly digitalized society (e.g., smart city)". The authors mentioned an increasingly digitalized society as also a core of a smart city, connecting it with the need of blockchain for managing key components of a distributed IoT network of devices. Naturally, some applications dealt with privacy concerns [54], since blockchain provides, for the first time in history, an open-source public infrastructure of cryptographic functions that enables applications related to privacy, such as the peer-reviewer process of scientific papers. Other applications are going beyond, such as Patel and Patel (2020) [55], which emphasizes that the technology of Distributed Applications (DApps) can handle the cities' data storage, data management, smart contracting, authentication, validation and trust-free transaction handling, and enable a shared economy. As highlighted by them, in the era of smart cities, it is inevitable to not consider a technology that provides immutable and transparent communication between interested parties. The work of Hakak et al. (2020) [56] mentioned that the purpose of SCs is also to enhance the quality of life for citizens dwelling within them. They made an effort in identifying blockchain components for working along with IoT and cloud computing. Some works of the literature considered blockchain for reputation [57] and payments on intelligent transportation systems [58], which is a topic of great interest for citizens, since many users are already registered with Uber and other private companies, which do not provide such decentralization of their services. The need of blockchain for these kind of services is essential for avoiding censorship and unfair behavior of companies.

While many works in the literature mentioned blockchain for IoT applications, we emphasize here that it also promotes, for the first time in history, IoV, which can be a path for monetization of different services provided by cities, as well as a channel for rewarding citizens. In the next subsections, blockchain concepts will be used in order to exemplify tools that blockchain can enable, as well as to work in parallel with existing solutions.

3.2. Challenges on Infrastructure

The wave of innovation in smart cities brings new interactive layers to cities, while it also simplifies and removes barriers from previous models. The key pillars are located in the interconnected sensors,

intelligent transportation systems (metro, train, drones), public space with gardens, automatic and efficient lighting, gas system, water, telecommunication and infrastructure for energy sharing.

Sensors and smart devices can be used to solve problems of urban traffic, optimizing current transportation systems and assisting the design of emerging ones [59]. Microgrid houses are generating electricity, known as prosumer (*pro*ducer + con*sumer*); these decentralized generation systems [60,61] also bring solutions to some areas of a city and also promote interaction of citizens and the possibilities that energy brings. Besides promoting sustainability, with the advance of cryptocurrencies, energy can also be a path to monetization, as introduced in Section 3.1.

Well-designed urban planning, associated with multi-criteria analysis about citizens' goals and wishes related to cities' services can guide a more sustainable transition. Studies of SC [62,63] can boost more effective mobility and fairer access to opportunities, especially for urban populations. Logistics involve citizens' life quality in different aspects, such as air quality, noise, access time to cities key point and security, among others.

These topics are naturally complex because they involve the sense of each individual; what could be an optimal solution for one is not the same for another. For this purpose, online software can play a vital role in assisting each specific person to follow their goal within a city. In this sense, vehicle routing problems [64] should consider these "green" variables, promoting sustainable routing that ponders citizens' desires, both for daily locomotion but also for medium-term projections about the most suitable place to live.

Cisco and New York City introduced a project named City 24/7, which seeks to provide information from open government programs, local business and citizens to provide meaningful and powerful knowledge anytime, anywhere, on any device. These interactive screens include touch screen, voice and audio technology and provide real-time offers. Besides that, these platforms can be accessed by low range communication protocols using smartphones [65], tablets and portable computers. Being located at bus stops, train stations, major entryways, shopping mall and other places, this platform informs, protects and revitalizes. Those types of screens are used for facilitating and instructing citizens regarding distinct services within cities, such as informing the population about the next buses on the way, as well its position in the route and expected times. The location of the bus is available for any smartphone that connects in the network or knows a pre-defined code available at bus stations on the screens. In particular, the work of Oliveira et al. (2020) [58] drafted a smart contract that could manage a transportation service with a payment system working with crypto tokens and optional data protection.

In order to determine "optimal" areas for installing such interactive screens, it is necessary to consider the set of streets, flow of citizens along the roads, position of the screen on the street and the costs, among other things. Operation research techniques can help decision making and minimization of involved costs. Besides that, determining a set of relevant information, considering the profile of each individual that accesses the device, is another possible problem to be dealt with. In this case, the system could consider individuals' preferences and the current wishes of those accessing the platform. This direct marketing problem [66] should present suitable offers for each person, promoting the local communities [67], increasing cities' income and social welfare and urban cleaning, among other things.

Multi-modal transportation is an interesting decision making process, as emphasized in [68] and [69], which highlighted optimization mechanisms and multi-criteria decision making for finding best sets of routes according to the different needs of each individual. As an example, Figure 4 depicts an illustrative example of the routes provided by Google Maps in Osaka, Japan. As can be verified, even the most suitable wagon of the metro is indicated in the app.

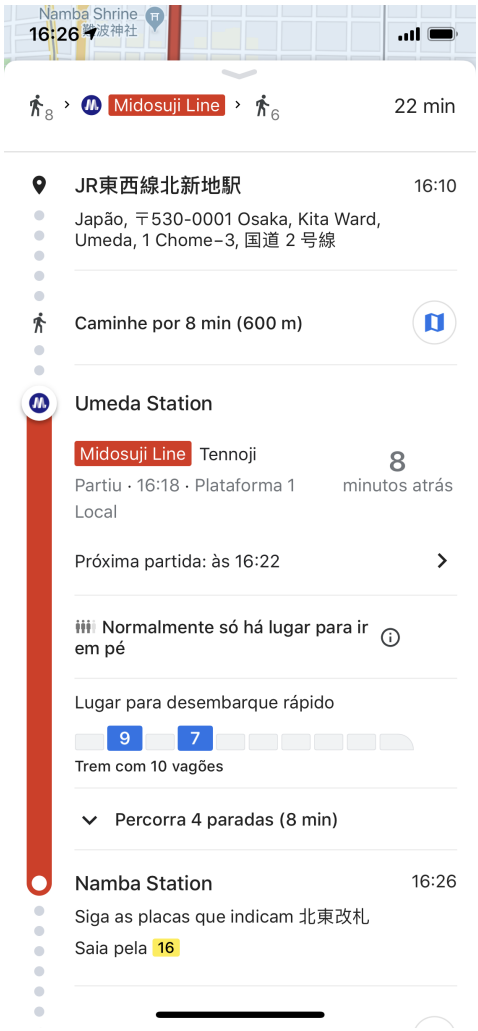


Figure 4. Google Maps routes showing faster wagons for landing, Osaka/Japan.

3.3. Improving Visitors' Experience

Protection of cultural heritage cities [70] is also within the scope of digital cities. SCs' interactive museums [71] are being inaugurated; they can guide the flow of information, such as news and technologies. For example, the Center for Teaching and Research in the Social Sciences and Contemporary History of Brazil from Getulio Vargas Foundation was founded in 1973, motivated by a need of conservation policies and digital dissemination [72]. The center contains the largest collection of personal archives from Brazilians' public figures, oral histories and audiovisual, covering social area, health care and architecture, among other things [73]. In this era of online available documents, this center verified the necessity of preserving its documents; in this sense, since 2010 they have been digitizing their collection (according to specific calls and actions), using semantic technologies, ICT, open linked data concepts and signal processing techniques. Since access is open in their domain, the collection has been considered to be relevant for both national and international studies. Sun et al. (2016) [27] comment that SC has a challenge to develop technologies to protect heritage items [74].

Besides the material heritage there is the immaterial, which covers typical cultures of each region (such as folklore, dance and ritual, among others), which are difficult to monitor in depth. Such a fact also applies in the north part of Brazil, in the interior of Amazonas state, as well as in others areas of South America. Smart measures should promote access to technology in order to assist the indigenous

people's immaterial heritage [75]. One option can be the introduction of novel tools for the indigenous to document their beliefs, promoting this material in a decentralized manner [76], through the Internet.

Computational intelligence based technologies such as interactive maps were discussed by Roche (2016) [77]. Visitors of a city [78] could get tokens when they visit strategic points marked on those interactive maps. The verification method and rewards could even be automatically managed by smart contracts, and the rewarding tokens could be minted by city authorities, representing a specific asset given by that community. Such tokens could be exchanged for services that benefit local communities and the city. The efforts that are being done for promoting green logistics of electric vehicles used in touristic routes [79] are also noteworthy and related to sustainability, and are connected with technologies such as blockchain [21]. Guiding each citizen to the area that they would like visit is a task that can provide different social and technical benefits. Towsend and Oakley (2014) [80] comment that future cities need to guide the citizens with on-time journeys. It is possible to emphasize that the technology comes to make the city and tourist relationship easier and more flexible, bringing proximity and integration. In this sense, visitors can be more involved in decisions, being informed about current government strategies, news and perspectives.

3.4. Decentralized Governance

As should be noticed, social science is becoming increasingly part of the smart city debate. Understanding citizens' views about where they live and how they feel is primordial. Assessments of some uses of ICT solutions have already revealed problems that can only be resolved by engaging citizens in planning processes. The concept of e-governance (also known as civic tech) has a role to play in how to engage citizens [81]. Summed up with this, we currently have a new wave of decentralization, which is crucial for low-cost and trusted governance. Concepts of blockchain should be carefully considered when e-governance is taken into account. For example, governance models such as the Neo Blockchain [82] are an example of successful association of digital assets and democracy. In this section, we emphasize some of these concepts related with a historical background of decentralization and e-governance.

Decentralized governance paradigms are now being frequently discussed [3], in particular, due to the recent advances in IoT and blockchain based solution which are turning the IoV [20] into a real tool for policy enforcement [83]. In this sense, there have been efforts in bringing more proximity between government and citizens [84–86]. Connected by a new era of information technologies, the SC drives a strong trend for decentralizing democracies [87], as mentioned by Roberts (2004) [88]. Decentralizing the decision-making process implies distributing decisions, a strategy that has been mainly adopted using the paradigm of Multi-Agent Systems (MAS) [89,90] concepts. The paradigm of MAS is related to devices achieving consensus [91] throughout negotiation protocols.

Democratic participation opens cognitive control of the state by the citizens through information technology applied for public transparency, such as using smart contracts [92]. Besides that, the concept of e-governance embraces strategic governance in management and institutional integration. Fundamental e-governance is based on an efficient governance of spaces and public services. Through this, the population can be more participatory and active during decision-making, both on small or medium scales, from neighborhoods to cities [93] and even on a wider global scale [94,95].

However, it is visible that tools are still missing for these kind of decisions. One simple example can be seen inside residential condominiums [96], where an useful tool for decision-making does not exist and condominiums' meetings persist in happening in a huge portion of these organizations. A useful way to fix this problem would be the installation of novel devices (like tablets) to enable real-time decision-making. This example circles around private city concepts [97,98].

The Internet has been adopted as the core for promoting more accessibility, a transformation that happens in a similar way as occurred with previous communications systems, from the telegraph to the TV. However, the Internet is allowing new forms of policy organization and, in society, increasing the

capacity of impacts in some individuals previously not interested [99]. In addition, nowadays, through IoT, communication channels are being opened by a larger portion of our used-daily devices. The IoT and related technologies can be used for policy and democratic purposes by a series of social agencies: Citizens, government organizations, civil society organizations and political parties, among others. What is expected, in terms of democratic innovation, is a shared decision-making process that means expanding the civil autonomy and public relations [100]. This provides space for e-government [101], and even possibilities of Internet voting [102,103], legislative and juridical decision-making [87,104] and public petitioning.

Dispute resolution based on blockchain solutions has also been developed, in a system called Kleros [105]. These processes are called civic tech, teledemocracy, digital democracy, electronic democracy, digital government, open administration, cyberdemocracy [100] or e-democracy [106]. Online forums, focused, for example, on allowing discussions on specific issues, are a consolidated way for providing an open environment for political activists and the opinions of sympathizers [107]. The blockchain guarantees forums of information permanently saved in an "immutable form"; in a way there are no changes or alterations [108] given that certificates are permanently stored. The immutability should be seen as a decentralized decision-making process, in which involved stakeholders can decide on the path they want to follow. In the case of the Ethereum and Bitcoin projects, one block finality is not achieved; in this sense, the chain can suffer deep reorganization (more details at https://en.bitcoin.it/wiki/Chain_Reorganization) if the majority of the nodes agree with the longest chain. Furthermore, the case in which Ethereum suffered an attack (on the occurrence of news about the DAO vulnerability: https://blog.ethereum.org/2016/06/17/critical-update-re-dao-vulnerability/) can be seen as an example of how discussions can reach a consensus of rolling the chain back to a point in which the state machine [109] was not affected. On the other hand, other protocols have block finality, such the Neo Blockchain [44], in which an MAS based consensus (namely, delegated byzantine fault tolerance) is held and nodes can not generate blocks in another branch, generating no forks. However, it is noteworthy that public blockchains have this nature of decentralization. Thus, in this sense, even in the case of the roll back of Ethereum, the chain that had been attacked still exists (namely, Ethereum Classic). Thus, the immutability in fact happens, but can be forgotten if the majority agrees to not consider that branch. The blockchain promotes the warranty of original information without changes. It is possible to conclude that the Internet is positively used in this context, helping in decision-making, improving communication models and data storage.

3.5. Citizens' Privacy

An increase in security usually implies less privacy. For example, with cameras to control the security and citizens' traffic, the citizens' identity and data become more visible [110,111], which is another reason why cryptography and blockchain become even more important topics. In 2019, some states of the USA banned the use of individual images in different situations, such as facial recognition; a requirement that fits the context of digital IDs and access to private data provided by blockchain. Applications for such public transparency need to be carefully addressed philosophically, as discussed by Byung-Chul Han, since trust should be kept as a main value between partnerships during exchange of information and assets. Recently, the philosopher has made some notes regarding the recent events related to the coronavirus outbreak [112,113]. He emphasizes that Asian countries have been using support of digital surveillance to fight the virus, while Western countries have been struggling with data regulations. He points out that it is possible that in the future the state will also have digital access to body temperature, weight and blood sugar level, among other things. In his insight, he highlights ICT tools such as notifying citizens that a given place has someone infected such as the Korean Corona App, a publicly available application that can inform citizens of known cases considering their current position [114]. However, concerns regarding the use of such data by Western states were also asserted by him.

CISCO [115] pointed out that investments on privacy have a positive return on investment. An appealing to blockchain is related to its features of transparency instead of the taboo of promoting anonymity [54]. Blockchain [116] plays a fundamental role in information access, mainly by using smart contracts [117] to ensure transparent protocols. IoV brings this optional potential of transparency by promoting a trusted network of computers which can work following different consensus mechanisms such as proof-of-work, proof-of-stake and other voting/negotiation systems. Examples of real-world use of asset exchanges can be seen in Bitcoin, Dash, Monero, ZCash and other emerging cryptocurrencies. Some of them have embedded anonymity and optional possibility of transparency. While enabling optional trust you preserve individual privacy [118] and enable an auditable system for special cases in which it may be needed. Yeh (2017) [2] mentioned that citizens show up to be excited if the ICT technologies, to be embedded inside cities' services, have data privacy policies. In order to achieve another level of social participation, it is important to promote easier ways of accessing information.

In this context, discussions surrounding digital identities are attracting attention of different blockchain projects. For instance, Neo Blockchain currently has three different proposals for managing digital identities on a public blockchain [119–121], introduced at the end of 2019 and under discussion regarding implementation until the end of 2020.

3.6. Innovation and Entrepreneurship in Smart Cities

The label "smart" has become a motto; nowadays, there are: Smart waters, smart cars and smart washlets, among others. "Smart" is becoming a brand, which mostly involves devices, tools and software that facilitate daily life. Policies related to SC have been attracting attention from a police maker and the industry, raising funding over the last few years [122]. Studies from the literature have been exploring the role of cities in enabling and facilitating digital entrepreneurship [123].

There is an open space for innovation when we take into account the sea of services that need minor adjustments. One of the bold ambitions is related to increasing the competitiveness of local communities [124], which has been one of the aims of scholars, practitioners and policy makers interested in this phenomenon. By promoting sustainable territorial development [13] there is a path for a sustainable transformation which would encompasses regulations but still boost innovation on the local scale. A case of study in Finland [125] notes that microenterprises need help with exploiting digitalization, indicating the potential that initiatives such as those commented on in this study can assist in that task.

Another interesting trend is in connection with the digitization of assets [126], which is promoting marketplaces for real-time exchange of value, not only involving cryptocurrencies such as bitcoin. This new trend is allowing citizens to interact with a variety of services by means of digital tokens that serve as utility such as the well-known mileage programs.

Lindgren et al. (2019) [127] comment on the digitalizations of public services that reduce the integration and duration of the citizen–governance interaction, but also require skills by providers and the population to use digital tools. Aligned with what was presented at Section 3.5, digital identities play another role in facilitating entrepreneurship, cutting the red tape of several processes as well as reducing costs.

4. Final Considerations

4.1. Conclusions

This study highlighted the evolution of concepts surrounding cities, an intrinsic part of modern society. Assisted by an analyses of the smart cities concepts and potential trends, this paper contributes with an updated position of cities' challenges, suggesting innovative opportunities, as can be seen in summary in Table 2.

Table 2. Summary of observations from key sub-categories with authors' analysis.

Sub-Categories	Descriptions/Observations	Authors' Recommendations
ICT	• It has been observed that works from the literature mention that smart cities' pillars are infrastructures throughout sensors and digital equipment; • These tools enable real time information sharing such as schedules of public transport, police and fire service stations, events, parks and outdoors activities, as well as a transparent layer for the use of technologies.	• ICT enables a new layer for a direct flow of information with citizens and services (an interactive layer); • One of the expected goals of ICT services is to provide relevant information for citizens, but few applications are really focused on User Experience (UX); • We have the challenge of promoting the digitalization of cities' services, thinking of users' perspectives; • This digitalization is not only a goal of the public administration but also of the software industry interested in attracting users to their platforms.
Governance	• Citizens can contribute to society through voting and other forms of social participation.	• Technologies aligned with the scope of SC have been bringing tools and discussions to this topic; • Policymakers need to understand that modern forms of governance need to rely on digital technology; • For achieving that, new frameworks need to be developed, providing easy access, facility, trust and transparency; • Decentralized technology is a key concept for governance and is just starting to be explored and investigated.
Blockchain	• It is recognized that this technology can support city initiatives for facilitating data transparency and trustless applications.	• Few applications and connections with cities and citizens are currently available in the literature, which is a challenge to be faced by researchers; • This tech and its application are becoming reality in some countries, with ideas that are starting to be implemented, but are not fully functional yet; • We have distinct limitations when using public chains. Thus, private chain interaction with public chains can provide a framework for different applications that preserve citizens' privacy and provide them a path for monetization.

It was highlighted that applications focused on citizens may promote decision making in a more effective way, both in urban centers and in small communities. As emphasized, digital technologies possess an important role to coordinate and optimize decisions, mainly due to the transformations regarding novel forms of governance.

4.2. Research Implications

The paper instigates a look on citizen relationships in a way to promote awareness among citizens regarding technological and digital evolution. Academicians can benefit from its insights in order to

find open problems and fields for improving a city, while the industry and cities' decision makers can use this study for guiding medium–long term plans for a sustainable transition.

In order to reduce the gap between citizens and technologies there is a need for more interactive systems, both on key points of a city and also better interfaces provided by the industry and the government. By facilitating access to governance tools, citizens will have quick access to services that assist their participation, wherever they are. For achieving that, society needs to rely on state-of-the-art technologies such as blockchain, which can act as a fundamental tool for trust, transparency and efficiency, supported by the evolution of equipment that ICT promotes. There is still a challenge in connecting social sciences with technologies; a huge portion of society still doubts that the technological evolution can improve life quality. It is a challenge to create awareness that the point we already reached in society was due to scientific advances and, at the end of the day, we still need our focus and efforts on that. While works from the literature have not yet directly focused on that, this study has the potential to create awareness of the academy and also boost startups to invest in emerging technologies and the development of highly interactive platforms. It is necessary to motivate investments and policies on topics related to citizens' participation in government decisions. These measures can provide opportunities for innovation connected with the use of those emerging tools.

Besides that, it is possible that a paradigm change, in the form of urban planning, will also be relevant. During this next decade, ICT and decentralized technologies, such as blockchain, are going to have an important role in processing data, communicating with citizens and assisting decision making through optimization tools, boosting the advance of social concepts surrounding governance and smart cities.

For instance, we conclude this paper by exemplifying a case in which some of the concepts of this research could be applied for a sustainable supply chain. Every worker would have his or her digital identity registered on a blockchain, as well as his or her historically relevant data such as vaccines and risks over the last days/weeks. Each farm and production line step of the supply chain would be registered in a distributed ledger through a smart contract. The way in which the soil and plants are treated could also be recorded on the blockchain in order to convey transparency for the production. This procedure facilitates certificates to be emitted (such as those for organic food). Following this line of reasoning, each truck used for collecting grains of coffee would be registered and those unloading them on the industry could take the necessary measures and keep the supply chain up to date. The final coffee obtained by a client could be scanned with a quick response code (or radio-frequency identification) that would provide awareness of the path the product has taken until its destination. Finally, clients could also provide scores and opinions on that product, affecting economical incentives provided for supporting that production.

This exemplifies a scenario in which citizens are provided with tools for tracking information that they desire to search for, as well as topics they want to give their opinions on.

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Abbreviations

The following abbreviations are used in this manuscript:

DApps	Distributed Applications
E-governance	Electronic governance
ICT	Information and Communication Technology
IoT	Internet of Things
IoV	Internet of Value
MAS	Multi-Agent Systems
SC	Smart City
UX	User Experience

References

1. Evans, A.M.; Campos, A. Open government initiatives: Challenges of citizen participation. *J. Policy Anal. Manag.* **2013**, *32*, 172–185. [CrossRef]
2. Yeh, H. The effects of successful ICT-based smart city services: From citizens' perspectives. *Gov. Inf. Q.* **2017**, *34*, 556–565. [CrossRef]
3. Coe, A.; Paquet, G.; Roy, J. E-governance and smart communities: A social learning challenge. *Soc. Sci. Comput. Rev.* **2001**, *19*, 80–93. [CrossRef]
4. Dameri, R.P.; Cocchia, A. Smart city and digital city: Twenty years of terminology evolution. In Proceedings of the X Conference of the Italian Chapter of AIS, ITAIS, Universitá Commerciale Luigi Bocconi in Milan, Italy, 14 December 2013; pp. 1–8. [CrossRef]
5. Gibson, D.V.; Kozmetsky, G.; Smilor, R.W. *The Technopolis Phenomenon: Smart Cities, Fast Systems, Global Networks*; Rowman & Littlefield: Lanham, MD, USA, 1992.
6. Stephen, G.; Marvin, S. *Telecommunications and the City: Electronic Spaces, Urban Places*; Routledge: Abingdon, UK, 1996.
7. Graham, S. Telecommunications and the future of cities: Debunking the myths. *Cities* **1997**, *14*, 21–29. [CrossRef]
8. Anthopoulos, L. Smart utopia VS smart reality: Learning by experience from 10 smart city cases. *Cities* **2017**, *63*, 128–148. [CrossRef]
9. Bina, O.; Inch, A.; Pereira, L. Beyond techno-utopia and its discontents: On the role of utopianism and speculative fiction in shaping alternatives to the smart city imaginary. *Futures* **2020**, *115*, 102475. [CrossRef]
10. Afonso, R.A.; dos Santos Brito, K.; do Nascimento, C.H.; Garcia, V.C.; Álvaro, A. Brazilian smart cities: Using a maturity model to measure and compare inequality in cities. In Proceedings of the 16th Annual International Conference on Digital Government Research, Phoenix, AZ, USA, 27–30 May 2015; pp. 230–238. [CrossRef]
11. Albino, V.; Berardi, U.; Dangelico, R.M. Smart cities: Definitions, dimensions, performance, and initiatives. *J. Urban Technol.* **2015**, *22*, 3–21. [CrossRef]
12. Ahvenniemi, H.; Huovila, A.; Pinto-Seppä, I.; Airaksinen, M. What are the differences between sustainable and smart cities? *Cities* **2017**, *60*, 234–245. [CrossRef]
13. Barbosa, A.C.; Moraes, T.M.; Tesima, D.T.; Pontes, R.C.; de Sá Motta Lima, A.; Azevedo, B.Z. Smart Planning: Tools, Concepts, and Approaches for a Sustainable Digital Transformation. In *Smart and Digital Cities: From Computational Intelligence to Applied Social Sciences*; Springer: Cham, Switzerland, 2019; pp. 221–236. [CrossRef]
14. Sadin, É. *L'humanité augmentée. L'administration Numérique du Monde*; Échappée (L'): Paris, France, 2013; ISBN 978-2915830750.
15. Han, B.C. *Transparenzgesellschaft*; Matthes & Seitz Berlin Verlag: Berlin, Germany, 2015.
16. Gilman, H.R. Civic Tech For Urban Collaborative Governance. *PS Political Sci. Politics* **2017**, *50*, 744–750. [CrossRef]
17. Guimarães, J.C.F.D.; Severo, E.A.; Júnior, L.A.F.; Costa, W.P.L.B.D.; Salmoria, F.T. Governance and quality of life in smart cities: Towards sustainable development goals. *J. Clean. Prod.* **2020**, *253*, 119926. [CrossRef]

18. Boehner, K.; DiSalvo, C. Data, design and civics: An exploratory study of civic tech. In Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems, San Jose, CA, USA, 7–12 May 2016; pp. 2970–2981. [CrossRef]
19. Nakamoto, S. *Bitcoin: A Peer-to-Peer Electronic Cash System*; White Paper; 2008. Available online: https://git.dhimmel.com/bitcoin-whitepaper/ (accessed on 13 September 2017).
20. Truong, N.B.; Um, T.W.; Zhou, B.; Lee, G.M. Strengthening the blockchain-based Internet of value with trust. In Proceedings of the 2018 IEEE International Conference on Communications (ICC), Kansas City, MO, USA, 20–24 May 2018; pp. 1–7. [CrossRef]
21. Sun, M.; Zhang, J. Research on the application of block chain big data platform in the construction of new smart city for low carbon emission and green environment. *Comput. Commun.* **2020**, *149*, 332–342. [CrossRef]
22. Lévy-Bencheton, C.; Darra, E.; European Union Agency for Network and Information Security. In *Cyber Security for Smart Cities: An Architecture Model for Public Transport*; ENISA: Heraklion, Greece, 2015; ISBN 978-92-9204-162-5. [CrossRef]
23. Oliveira, T.A.; Coelho, V.N.; Tavares, W.; Ramalhinho, H.; Oliver, M. Operational and digital challenges to connect citizens in smart cities (In portuguese). In Proceedings of the XLIX Annual Brazilian Symposium on Operational Research, Blumenau, Brazil, 17–30 August 2017; pp. 3819–3830.
24. Creating City. Proceedings organized by the Creating. City Team. 2020. Available online: https://creating.city/ (accessed on 3 February 2020)
25. Yin, C.; Xiong, Z.; Chen, H.; Wang, J.; Cooper, D.; David, B. A literature survey on smart cities. *Sci. China Inf. Sci.* **2015**, *58*, 1–18. [CrossRef]
26. Sassen, S. The global city: Introducing a concept. *Brown J. World Aff.* **2004**, *11*, 27.
27. Sun, Y.; Song, H.; Jara, A.J.; Bie, R. Internet of Things and Big Data Analytics for Smart and Connected Communities. *IEEE Access* **2016**, *4*, 766–773. [CrossRef]
28. Yao, T.; Huang, Z.; Zhao, W. Are smart cities more ecologically efficient? Evidence from China. *Sustain. Cities Soc.* **2020**, 102008. [CrossRef]
29. International Standards Organization. *Smart Cities–Preliminary Report 2014*; ISO 2015: Geneva, Switzerland, 2014.
30. Bollier, D. *How Smart Growth Can Stop Sprawl: A Fledgling Citizen Movement Expands*; Essential Books; Essential Books: Washington, DC, USA, 1998.
31. Hou, Q.; Li, W.; Zhang, X.; Fang, Y.; Duan, Y.; Zhang, L.; Liu, W. Intelligent urban planning on smart city blocks based on bicycle travel data sensing. *Comput. Commun.* **2020**, *153*, 26–33. [CrossRef]
32. Lennard, S.H.C. Livable Cities: Concepts and Role in Improving Health. In *Integrating Human Health into Urban and Transport Planning*; Springer: Cham, Switzerland, 2019; pp. 51–71.
33. Zhuhadar, L.; Thrasher, E.; Marklin, S.; de Pablos, P.O. The next wave of innovation—Review of smart cities intelligent operation systems. *Comput. Hum. Behav.* **2017**, *66*, 273–281. [CrossRef]
34. Taylor, P.J.; Derudder, B. *World City Network: A Global Urban Analysis*; Routledge: Abingdon, UK, 2015. [CrossRef]
35. Zambonelli, F. Toward Sociotechnical Urban Superorganisms. *Computer* **2012**, *45*, 76–78. [CrossRef]
36. Paulin, A.A. Informating public governance: Towards a basis for a digital ecosystem. In *Open Government: Concepts, Methodologies, Tools, and Applications*; IGI Global: Hershey, PA, USA, 2020; pp. 1534–1555. [CrossRef]
37. Evans, M.; Dunleavy, P.; McGregor, C.; Halupka, M. 10 Towards digital era governance: Lessons from the Australian experience. In *A Research Agenda for Public Administration*; Elgar Research Pub: Cheltenham, UK, 2019; p. 146. [CrossRef]
38. Chamoso, P.; González-Briones, A.; Prieta, F.D.L.; Venyagamoorthy, G.K.; Corchado, J.M. Smart city as a distributed platform: Toward a system for citizen-oriented management. *Comput. Commun.* **2020**, *152*, 323–332. [CrossRef]
39. Batty, M. Big data, smart cities and city planning. *Dialogues Hum. Geogr.* **2013**, *3*, 274–279. [CrossRef]
40. Web of Science. *Web of Science–Search for Smart Cities Publications*; 2017. Available online: https://mjl.clarivate.com/home (accessed on 11 February 2020).
41. SCOPUS. Analyse Search Results–Search for Smart Cities Publications. 2017. Available online: https://www-scopus-com.sare.upf.edu/search/form.uri?display=basic (accessed on 11 February 2020).
42. IEEEXplore. Analyse Search Results–Search for Smart Cities Publications. 2017. Available online: https://ieeexplore.ieee.org/Xplore/home.jsp (accessed on 11 February 2020).

43. Mossberger, K.; Wu, Y.; Crawford, J. Connecting citizens and local governments? Social media and interactivity in major US cities. *Gov. Inf. Q.* **2013**, *30*, 351–358. [CrossRef]
44. Da, F.; Zhang, E. *NEO: A Distributed Network for the Smart Economy*; Technical Report; NEO Foundation. Available online: https://github.com/neo-project/neo (accessed on 28 March 2020).
45. Perlman, L. *Distributed Ledger Technologies and Financial Inclusion*; Technical Report; ITU-T Focus Group Digital Financial Services; 2017. Available online: https://www.itu.int/en/ITU-T/focusgroups/dfs/Pages/default.aspx (accessed on 20 March 2018).
46. Foundation, The Linux Introduction to Hyperledger Technologies. 2017. Available online: https://www.edx.org/course/blockchain-business-introduction-linuxfoundationx-lfs171x (accessed on 20 January 2018).
47. Blockchains for Social Good. Available online: https://ec.europa.eu/research/eic/index.cfm?pg=prizes_blockchains (accessed on 10 December 2019).
48. Kshetri, N. Can blockchain strengthen the Internet of things? *IT Prof.* **2017**, *19*, 68–72. [CrossRef]
49. Sun, J.; Yan, J.; Zhang, K.Z. Blockchain-based sharing services: What blockchain technology can contribute to smart cities. *Financ. Innov.* **2016**, *2*, 26. [CrossRef]
50. BNDES. BNDES Token. 2020. Available online: https://github.com/bndes/bndestoken (accessed on 15 February 2020.)
51. Oliver, M.; Moreno, J.; Prieto, G.; Benítez, D. Using blockchain as a tool for tracking and verification of official degrees: Business model. In Proceedings of the 29th European Regional Conference of the International Telecommunications Society (ITS): "Towards a digital future: Turning technology into markets?", Trento, Italy, 1–4 August 2018.
52. Dobrovnik, M.; Herold, D.; Fürst, E.; Kummer, S. Blockchain for and in Logistics: What to Adopt and Where to Start. *Logistics* **2018**, *2*, 18. [CrossRef]
53. Aggarwal, S.; Chaudhary, R.; Aujla, G.S.; Kumar, N.; Choo, K.K.R.; Zomaya, A.Y. Blockchain for smart communities: Applications, challenges and opportunities. *J. Netw. Comput. Appl.* **2019**, *144*, 13–48. [CrossRef]
54. Makhdoom, I.; Zhou, I.; Abolhasan, M.; Lipman, J.; Ni, W. PrivySharing: A blockchain-based framework for privacy-preserving and secure data sharing in smart cities. *Comput. Secur.* **2020**, *88*, 101653. [CrossRef]
55. Patel, V.; Patel, C. Blockchain Technology: An Aid to the Governance of Smart Cities. *Adv. Intell. Syst. Comput.* **2020**, *933*, 373–382. [CrossRef]
56. Hakak, S.; Khan, W.; Gilkar, G.; Imran, M.; Guizani, N. Securing Smart Cities through Blockchain Technology: Architecture, Requirements, and Challenges. *IEEE Netw.* **2020**, *34*, 8–14. [CrossRef]
57. Hîrtan, L.A.; Dobre, C.; González-Vélez, H. Blockchain-based reputation for intelligent transportation systems. *Sensors (Switzerland)* **2020**, *20*, 791. [CrossRef]
58. Oliveira, T.A.; Gabrich, Y.B.; Ramalhinho, H.; Oliver, M.; Cohen, M.W.; Ochi, L.S.S.; Gueye, S.; Protti, F.; Pinto, A.A.A.; Ferreira, D.V.M.V.M.; et al. Mobility, Citizens, Innovation and Technology in Digital and Smart Cities. *Future Internet* **2020**, *12*, 22. [CrossRef]
59. Clarke, R.Y. *Smart Cities and the Internet of Everything: The Foundation for Delivering Next-Generation Citizen Services*; White Paper; Cisco: San Jose, CA, USA, 2013.
60. Coelho, V.N.; Coelho, I.M.; Coelho, B.N.; de Oliveira, G.C.; Barbosa, A.C.; Pereira, L.; de Freitas, A.; Santos, H.G.; Ochi, L.S.; Guimarães, F.G. A communitarian microgrid storage planning system inside the scope of a smart city. *Appl. Energy* **2017**, *201*, 371–381. [CrossRef]
61. Darby, S.J. Chapter 2.6 - Energy, human activity, and knowledge: Addressing smart city challenges. In *Energy and Behaviour*; Lopes, M., Antunes, C.H., Janda, K.B., Eds.; Academic Press: Cambridge, MA, USA, 2020; pp. 237–260. [CrossRef]
62. Cano, J.; Hernández, R.; Ros, S. Distributed Framework for Electronic Democracy in Smart Cities. *Computer* **2014**, *47*, 65–71. [CrossRef]
63. Batty, M.; Axhausen, K.W.; Giannotti, F.; Pozdnoukhov, A.; Bazzani, A.; Wachowicz, M.; Ouzounis, G.; Portugali, Y. Smart cities of the future. *Eur. Phys. J. Spec. Top.* **2012**, *214*, 481–518. [CrossRef]
64. Coelho, V.; Grasas, A.; Ramalhinho, H.; Coelho, I.; Souza, M.; Cruz, R. An ILS-based algorithm to solve a large-scale real heterogeneous fleet VRP with multi-trips and docking constraints. *Eur. J. Oper. Res.* **2016**, *250*, 367–376. [CrossRef]
65. Falaki, H.; Govindan, R.; Estrin, D. *Smart Screen Management on Mobile Phones*; Center for Embedded Network Sensing: Los Angeles, CA, USA, 2009; pp. 1–10.

66. Coelho, V.N.; Oliveira, T.A.; Coelho, I.M.; Coelho, B.N.; Fleming, P.J.; Guimarães, F.G.; Ramalhinho, H.; Souza, M.J.; Talbi, E.G.; Lust, T. Generic Pareto local search metaheuristic for optimization of targeted offers in a bi-objective direct marketing campaign. *Comput. Oper. Res.* **2017**, *78*, 578–587. [CrossRef]
67. Barbosa, A.C.; Oliveira, T.A.; Coelho, V.N. Cryptocurrencies for Smart Territories: An exploratory study. In Proceedings of the 2018 International Joint Conference on Neural Networks (IJCNN), Rio, Brazil, 8–13 July 2018; pp. 1–8. [CrossRef]
68. Silva, J.; Rampazzo, P.B.; Yamakami, A. Urban Mobility in Multi-Modal Networks Using Multi-Objective Algorithms. In *Smart and Digital Cities: From Computational Intelligence to Applied Social Sciences*; Springer: Cham, Switzerland, 2019; pp. 9–22. [CrossRef]
69. Shirabayashi, J.V.; Yamakami, A.; Silva, R.C.; Shirabayashi, W.V.I., Urban Transport and Traffic Systems: An Approach to the Shortest Path Problem and Network Flow Through Colored Graphs. In *Smart and Digital Cities: From Computational Intelligence to Applied Social Sciences*; Springer: Cham, Switzerland, 2019; pp. 23–43. [CrossRef]
70. Lillevold, K.; Haarstad, H. The deep city: Cultural heritage as a resource for sustainable local transformation. *Local Environ.* **2019**, *24*, 329–341. [CrossRef]
71. Giannini, T. *Museums and Digital Culture*; Springer: Cham, Switzerland, 2019. [CrossRef]
72. Castro, R.M.D. Personal Files, Availability and Access on the Web: The case of CPDOC (In Portuguese). 2017. Available online: https://cpdoc.fgv.br/ (accessed on 10 July 2019).
73. Rademaker, A.; Higuchi, S.; Oliveira, D.A.B. A Linked Open Data Architecture for Contemporary Historical Archives. In Proceedings of the 3rd International Workshop on Semantic Digital Archives (SDA 2013), Valetta, Malta, 26 September 2013; pp. 52–64.
74. Zhou, Y.; Sun, J.; Huang, Y. The Digital Preservation of Intangible Cultural Heritage in China: A Survey. *Preserv. Digit. Technol. Cult.* **2019**, *48*, 95–103. [CrossRef]
75. Hoffmann, Z. Information and communication technologies in bachelor degree of intercultural education of native ameridian teachers of Federal University of Goiás. Ph.D. Thesis, Postgraduate Program in Science and Mathematics Education. University of Goiás, Goiânia, Brazil, 2015.
76. Bueno, C. Comunidades indígenas usam Internet e redes sociais para divulgar sua cultura. *Ciência E Cult.* **2013**, *65*, 14–15. [CrossRef]
77. Roche, S. Geographic information science III Spatial thinking, interfaces and algorithmic urban places-Toward smart cities. *Prog. Hum. Geogr.* **2017**, *41*, 657–666. [CrossRef]
78. Matos, A.; Pinto, B.; Martins, S.; Martins, J.; Au-Yong-Oliveira, M. Smart Cities and Smart Tourism: What Future Do They Bring? In *New Knowledge in Information Systems and Technologies*; Rocha, Á., Adeli, H., Reis, L.P., Costanzo, S., Eds.; Springer: Cham, Switzerlands, 2019; pp. 358–370.
79. Karbowska-Chilinska, J.; Zabielski, P. Maximization of Attractiveness EV Tourist Routes. In *Computer Information Systems and Industrial Management*; Saeed, K., Homenda, W., Chaki, R., Eds.; Springer: Cham, Switzerlands, 2017; pp. 514–525. [CrossRef]
80. Townsend, P.S.; Oakley, C.F. Innovative provision for pedestrians in future intelligent cities. In Proceedings of the IET Conference on Future Intelligent Cities, London, UK, 4–5 December 2014; pp. 1–6. [CrossRef]
81. Gilman, H.R. *Participatory Budgeting and Civic Tech: The Revival of Citizen Engagement*; Georgetown University Press: Washington, DC, USA, 2016.
82. Elrom, E. NEO Blockchain and Smart Contracts. In *The Blockchain Developer: A Practical Guide for Designing, Implementing, Publishing, Testing, and Securing Distributed Blockchain-based Projects*; Apress: Berkeley, CA, USA, 2019; pp. 257–298. [CrossRef]
83. Neisse, R.; Steri, G.; Nai-Fovino, I. A blockchain-based approach for data accountability and provenance tracking. In Proceedings of the 12th International Conference on Availability, Reliability and Security, Reggio Calabria, Italy, 29 August–1 September 2017; p. 14. [CrossRef]
84. Almirall, E.; Wareham, J.; Ratti, C.; Conesa, P.; Bria, F.; Gaviria, A.; Edmondson, A. Smart Cities at the Crossroads: New Tensions in City Transformation. *Calif. Manag. Rev.* **2016**, *59*, 141–152. [CrossRef]
85. Odendaal, N. Towards the digital city in South Africa: Issues and constraints. *J. Urban Technol.* **2006**, *13*, 29–48. [CrossRef]
86. Stepan, A. Brazil's Decentralized Federalism: Bringing Government Closer to the Citizens? *Daedalus* **2000**, *129*, 145–169. [CrossRef]

87. Coelho, V.N.; Oliveira, T.A.; Figueiredo, I.V.O.; Souza, M.J.F.; Veloso, I. A Multicriteria View about Judicial and Legislative Decision Making in Digital Cities and Societies. In *Smart and Digital Cities: From Computational Intelligence to Applied Social Sciences*; Springer: Cham, Switzerlands, 2019; pp. 209–220. [CrossRef]
88. Roberts, N. Public Deliberation in an Age of Direct Citizen Participation. *Am. Rev. Public Adm.* **2004**, *34*, 315–353. [CrossRef]
89. Coelho, V.N.; Cohen, M.W.; Coelho, I.M.; Liu, N.; Guimarães, F.G. Multi-agent systems applied for energy systems integration: State-of-the-art applications and trends in microgrids. *Appl. Energy* **2017**, *187*, 820–832. [CrossRef]
90. Chalkiadakis, G.; Elkind, E.; Polukarov, M.; Jennings, N.R. The Price of Democracy in Coalition Formation. In *Proceedings of the 8th International Conference on Autonomous Agents and Multiagent Systems—Volume 1*; International Foundation for Autonomous Agents and Multiagent Systems: Richland, SC, USA,2009; pp. 401–408.
91. Wylie, B. *Open Data Endgame: Countering the Digital Consensus*; Papers No. 186; Centre for International Governance Innovation: Waterloo, ON, Canadá, 2018; pp. 1–22.
92. Nugent, T.; Upton, D.; Cimpoesu, M. Improving data transparency in clinical trials using blockchain smart contracts. *F1000Research* **2016**, *5*. [CrossRef]
93. Chourabi, H.; Nam, T.; Walker, S.; Gil-Garcia, J.R.; Mellouli, S.; Nahon, K.; Pardo, T.A.; Scholl, H.J. Understanding Smart Cities: An Integrative Framework. In Proceedings of the 2012 45th Hawaii International Conference on System Sciences, Maui, HI, USA, 4–7 January 2012; pp. 2289–2297. [CrossRef]
94. Coelho, V.N.; Coelho, I.M.; Oliveira, T.A.; Ochi, L.S. *Smart and Digital Cities: From Computational Intelligence to Applied Social Sciences*; Springer: Cham, Switzerlands, 2019.
95. Oliveira, T.A.; Coelho, V.N.; Ramalhinho, H.; Oliver, M. Digital Cities and Emerging Technologies. In *Smart and Digital Cities: From Computational Intelligence to Applied Social Sciences*; Springer: Cham, Switzerlands, 2019; pp. 197–207. [CrossRef]
96. Cruz, S.S.; Pinho, P. Closed Condominiums as Urban Fragments of the Contemporary City. *Eur. Plan. Stud.* **2009**, *17*, 1685–1710. [CrossRef]
97. Nelson, R.H. *Private Neighborhoods and the Transformation of Local Government*; The Urban Institute: Washington, DC, USA, 2005.
98. Glasze, G.; Webster, C.; Frantz, K. *Private Cities: Global and Local Perspectives*; Routledge: Abingdon, UK, 2006. [CrossRef]
99. Hindman, M. *The Myth of Digital Democracy*; Princeton University Press: Princeton, NJ, USA, 2009.
100. Colombo, C. Innovación democrática y TIC, ¿hacia una democracia participativa? *IDP: Revista De Internet, Derecho Y Política = Revista DÍnternet, Dret I Política*; Universitat Oberta de Catalunya: Barcelona, España, **2006**; Volume 3, p. 7. [CrossRef]
101. Lemos, A.; Lévy, P. *O futuro da Internet: Em direção a uma ciberdemocracia*; PAULUS Editora: São Paulo, SP, Brazil, 2010; p. 264.
102. Sayyad, S.; Pawar, M.; Patil, A.; Pathare, V.; Poduval, P.; Sayyad, S.; Pawar, M.; Patil, A.; Pathare, V.; Poduval, P. Features of Blockchain Voting: A Survey. *Int. J.* **2019**, *5*, 12–14.
103. Lévy, P. *Ciberdemocracia. Tradução de Alexandre Emílio*; Instituto Piaget: Lisboa, Portugal, 2002.
104. Coelho, V.N.; Veloso, I.F.O.; Oliveira, T.A.; Coelho, V.N.; Veloso, I.; Veloso, V.M.; Souza, M.J.F.; Filho, A.F.S. A multi-criteria view about judicial and legislative decision making in digital cities and societies. In Proceedings of the XLIX Annual Brazilian Symposium on Operational Research, Blumenau, Brazil, 17–30 August 2017; pp. 3979–3989. (In Portuguese)
105. Allen, D.W.; Lane, A.; Poblet, M. The Governance of Blockchain Dispute Resolution. 2019. Available online: http://dx.doi.org/10.2139/ssrn.3334674 (accessed on 17 January 2020).
106. Martí, J.L. Alguna precisión sobre las nuevas tecnologías y la democracia deliberativa. *IDP: Revista De Internet, Derecho Y Política = Revista DÍnternet, Dret I Política*; Universitat Oberta de Catalunya: Barcelona, España, 2008; Volume 6, p. 7. [CrossRef]
107. Kies, R. *Promises and Limits of Web-Deliberation*; Springer: Berlin, Germany, 2010. [CrossRef]
108. Lemos, R. Using the Blockchain for the Public Interest, 2016. Available online: https://medium.com/positive-returns/using-the-blockchain-for-the-public-interest-2ed1f5114036 (accessed on 12 October 2017).
109. Schneider, F.B. Implementing Fault-tolerant Services Using the State Machine Approach: A Tutorial. *ACM Comput. Surv.* **1990**, *22*, 299–319. [CrossRef]

110. Laufs, J.; Borrion, H.; Bradford, B. Security and the smart city: A systematic review. *Sustain. Cities Soc.* **2020**, *55*, 102023. [CrossRef]
111. Ae Chuna, S.; Shulmanb, S.; Sandovalc, R.; Hovyd, E. Government 2.0: Making connections between citizens, data and government. *Inf. Polity* **2010**, *15*, 1–9. [CrossRef]
112. Han, B.C. Gesellschaft. 2020. Available online: https://www.perlentaucher.de/9punkt/2020-03-23.html (accessed on 23 March 2020).
113. País, E. The Coronavirus of Today and the World of Tomorrow, by the Phylopher Byung-Chul Han. 2020. Available online: Available online: https://brasil.elpais.com/ideas/2020-03-22/o-coronavirus-de-hoje-e-o-mundo-de-amanha-segundo-o-filosofo-byung-chul-han.html?rel=mas (accessed on 22th March, 2020).
114. Dudden, A. South Korea Took Rapid, Intrusive Measures Against Covid-19 – and they Worked. 2020. Available online: https://www.theguardian.com/commentisfree/2020/mar/20/south-korea-rapid-intrusive-measures-covid-19 (accessed on 23th March 2020).
115. CISCO. *From Privacy to Profit: Achieving Positive Returns on Privacy Investments—Data Privacy Benchmark Study*; Technical Report, CISCO CYBERSECURITY SERIES; Cisco: San Jose, CA, USA, 2020.
116. Liu, L.; Xu, B. Research on information security technology based on blockchain. In Proceedings of the 2018 IEEE 3rd International Conference on Cloud Computing and Big Data Analysis (ICCCBDA), Chengdu, China, 20–22 April 2018; pp. 380–384. [CrossRef]
117. Luu, L.; Chu, D.H.; Olickel, H.; Saxena, P.; Hobor, A. Making smart contracts smarter. In Proceedings of the 2016 ACM SIGSAC Conference on Computer and Communications Security, Vienna, Austria, 24–28 October 2016; pp. 254–269. [CrossRef]
118. Bouchelaghem, S.; Omar, M. Secure and efficient pseudonymization for privacy-preserving vehicular communications in smart cities. *Comput. Electr. Eng.* **2020**, *82*, 106557. [CrossRef]
119. SueNEO. Design of AthenaID. 2020. Available online: https://github.com/neo-project/neo/issues/1306 (accessed on 22 February 2020).
120. lllwvlvwlll. [NeoID] Design of Moonlight. 2020. Available online: https://github.com/neo-project/neo/issues/1313 (accessed on on 22 February 2020).
121. SueNEO. [NeoID] Design, Discussion and Implementation. 2020. Available online: https://github.com/neo-project/neo/issues/1304 (accessed on 22 February 2020).
122. Caragliu, A.; Bo, C.F.D. Smart innovative cities: The impact of Smart City policies on urban innovation. *Technol. Forecast. Soc. Chang.* **2019**, *142*, 373–383. doi:10.1016/j.techfore.2018.07.022. [CrossRef]
123. Geissinger, A.; Laurell, C.; Sandström, C.; Eriksson, K.; Nykvist, R. Digital entrepreneurship and field conditions for institutional change—Investigating the enabling role of cities. *Technol. Forecast. Soc. Chang.* **2019**, *146*, 877–886. [CrossRef]
124. Appio, F.P.; Lima, M.; Paroutis, S. Understanding Smart Cities: Innovation ecosystems, technological advancements, and societal challenges. *Technol. Forecast. Soc. Chang.* **2019**, *142*, 1–14. [CrossRef]
125. Räisänen, J.; Tuovinen, T. Digital innovations in rural micro-enterprises. *J. Rural Stud.* **2020**, *73*, 56–67. [CrossRef]
126. Lee, J.Y. A decentralized token economy: How blockchain and cryptocurrency can revolutionize business. *Bus. Horizons* **2019**, *62*, 773–784. [CrossRef]
127. Lindgren, I.; Østergaard Madsen, C.; Hofmann, S.; Melin, U. Close encounters of the digital kind: A research agenda for the digitalization of public services. *Gov. Inf. Q.* **2019**, *36*, 427 – 436. [CrossRef]
128. Coelho, V.N.; Coelho, I.M.; A.Oliveira, T.; Ochi, L.S. (Eds.) *Smart and Digital Cities*; Springer: Cham, Switzerlands, 2019. [CrossRef]

Oliveira, T.A., Coelho, V.N., Ramalhinho, H., Oliver, M. (2018). Digital Cities and Emerging Technologies. Urban Computing. 1ed.: Springer International Publishing, 2019, v. 1, p. 197-207. [Oliveira et al., 2019]

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Digital cities and emerging technologies

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Abstract Cities are undergoing transformations in several respects, but, mainly, regarding novel technologies. In this sense, the aim of this study is to understand the relation between the cities and the use of emerging technologies such as digital democracy, blockchain and, in particular, smart contracts. In the direction of discuss and analyze the possibilities of this evolution and transformation, a bibliometric search is carried out in this chapter. A search of keywords in some refereed world databases was made: Springer, SCOPUS, IEEExplore, Science Direct, Google Trends, Web of Science and Taylor & Francis. This combination of databases was selected in order to become possible to reach a high coverage of numbers of works about Digital City and related technologies.

1 Introduction

Cities have been evolving along with the humankind. From modern ecovillages, smart condominiums, digital urban and sustainable rural areas, society have been using Information and Communication Technologies for our humans benefits [6], [28]. The evolution is now been driven by a sea of shared information, sometimes called big-data. Fully distributed cities can now reach agreements and evolute in accordance with the wishes and goals of those who lives there. According to Batty

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and Marshall (2009) [9], cities are "a collection of elements that act independently of one another but nevertheless manage to act in concert." [p. 567].

The computer science have a "(...) a progressive approach to urban studies started during the last years of the twentieth century when the digital revolution began to transform urban areas" [21][p. 4] in a "constellation of computers" [8] [p. 155]. The ICT (Information and communication technologies) also have an important position in this digital revolution, because of its accomplishment for innovations and support to the new science of cities [21].

This chapter is developing the works that have been done in the researches [7], [13], [14], [23], [24], [25], these articles approach smart cities, challenges to connect SC and citizens, as well as new cities' technologies that came to facilitate citizens life, marketing, digital cities, among others. The team of researchers has been participating on congress and conferences, also organizing special sessions and round tables, sharing knowledge and learning with other researchers who work with different themes in the field of Smart and Digital Cities. In these studies they pointed ways for the citizens to be more participatory in cities decisions' together with the government and new forms of judicial and legislative decision making in digital cities. Forward the inclusion of technologies that are coming, as blockchain, smart contract, digital democracy, to restructure the way we store data and manage information [29], that can be applied by the government to have more trust in our shared information.

The concept around Digital Cities is broad, involving technology and infrastructures that aims to build good interactions between human kind and technologies, becoming a reference and indicator to develop the urban innovation and receiving more attention from universities and researchers around the world [21]. According to Nam and Pardo (2011) [22], the concept of Digital City is about the "integration of infrastructures and technology-mediated services, social learning for strengthening human infrastructure, and governance for institutional improvement and citizen engagement." (p. 282).

This chapter explores the Digital City (DC), connecting sustainable and emerging technologies, such as: Blockchain; Smart Contracts; and Digital Democracy.

Through a bibliographic research this chapter analyses the relations between these technologies with the aim of discussing what are the impacts of digital democracy, blockchain and smart contract for Digital City and how these concepts differ and correlate among them.

In this sense, the contributions of this work involves:

- Analyze studies between the DC with blockchain, digital democracy and smart contract;
- Comparing the publications in each area;
- Analyze the relevance of these terms to cities' evolution;
- Consider the impact of these therms in the context of Smart Cities and DC.

The remainder of this Chapter is organized as follows: Section 2 presents a background surround the aforementioned themes, a bibliographic search is conducted at Section 3 and the final considerations and future works are presented at Section 4.

2 Background

In this section, we presented a general view about cities in the Section 2.1, in particular, the Blockchain technology and Smart Contracts are presented at Sections 2.2 and 2.3, respectively, while Digital Democracy is approached at Section 2.4.

2.1 Cities' evolution: connecting real, sustainable, smart and digital cities

Technologies are surely the basins of human development. Since plenty of year ago, the humankind has been using its skills for achieving better life quality. The evolution of the species [15], undoubtedly, guided the permanence of those who are able to refine their arts from those technological tools. The word "Techne" means art, skill, craft, or the way, manner, or means by which a thing is gained. The roman philosopher Cicero commented [11] that humans had an ability of transforming the environment and, consequently, creating a "second nature". The evolution is an environment that evolves in accordance with those who manage and govern that space. Technology, in the deep sense of view, is not only related to digital and computational intelligence technologies, but can reach different aspects according to the desired evolution that a group of individuals are working on.

Cities, ubiquitous and smart cities are usually advocated as: "(...) a model of city where information systems are sharing data, like the cloud computing." [1]. The International Organization for Standardization complements that "Developing Smart Cities can benefit synchronized development, industrialization, informatization, urbanization and agricultural modernization and sustainability of cities development." ISO2014 (p.02) [26]. Around the definition of term for a intelligent city, different authors defend distinct points of view. For instance, Ahvenniemi et al. (2017) mentions that a city that is not sustainable is not really "smart". Furthermore, the authors add that "Sustainability assessment should be part of the SC development and therefore we find it important to integrate sustainability and smart city frameworks, so that both views are accounted for in performance measurement systems (...)" (p. 235) [2]. Finally, Ahvenniemi et al. (2017) recommended the use the term: "smart sustainable cities" instead of "smart cities". On the other hand, Smart City or Digital City can be seen as a cyber-physical integration in the urban space, along this chapter these terms will be used in order to approach the concept of cities of the future.

2.2 Blockchain technology

Blockchain is a nomenclature attributed for a new distributed and information technologies that have the objective to save data on immutable and secure way [19], [20]. According to Galen et. al (2018):

> "A blockchain is a digital, secure, public record book of transactions (a ledger). "Block" describes the way this ledger organizes transactions into blocks of data, which are then organized in a "chain" that links to other blocks of data. The links make it easy to see if anyone has changed any part of the chain, which helps the system protect against illegal transactions." (p. 06, [16]).

When the information reaches the Blockchain, it becomes impossible to change its historical path, in this sense, the data became immutable [19]. Due to this, blockchain can be applied in different areas, offering a solution where reliable registration is required and becomes trusted [20]. Furthermore, there is also the decentralized concepts, which has the potential of bringing low cost solutions. In the context of digital cities, blockchain can be used for social impact and to record government decisions, monetary transactions, state of the documents, projects and plans. The blockchain involves three pillars and attributes: trust, transparency and immutability. Figure 1 was drawn for representing them.

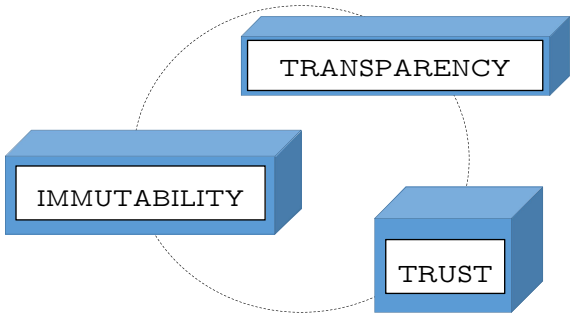

Fig. 1 Blockchain pillars.

Figure 1 shows those aforementioned blockchain attributes, which can be applied in different areas in the city, as in the governance, health care, voting system, among others. In order to complement it, the concept of smart contract will be addressed in the Section 2.3.

2.3 Smart Contracts

Along with the Blockchain comes the idea of Smart Contracts, which involve electronic protocols that digitally check and automatically executed pre-defined con-

tracts (negotiations, agreements, among others). The contracts evolve in a automatically fashion, executed by rules throughout a decentralized system that is extremely hard to be stopped [16]. In summary, a smart contract works as a code container that encode and reflect real-world contract in the cyber world.

Each contract represents an agreement made by two or more parts, where each part must fulfill its obligation under that pre-defined contract [20]. Figure 2 illustrates a smart contract and its interaction with different parties. First, someone needs to create the contract with some programming rules (written in well-known programming languages), then, that contract is deployed into the network and becomes accessible for everyone connected. The contract is automatically executed by a network of computers, in this sense, public contracts become available for those who wants to use them. For example, a given contract C_y can be made available for a defined set of addresses $[A_1, A_2, ..., A_n]$ with predefined rules. In the case of private interests, private blockchain solutions can be used, creating a system which is accessible only for authorized agents. In the Figure 2, the entity can be a company, a person, among others.

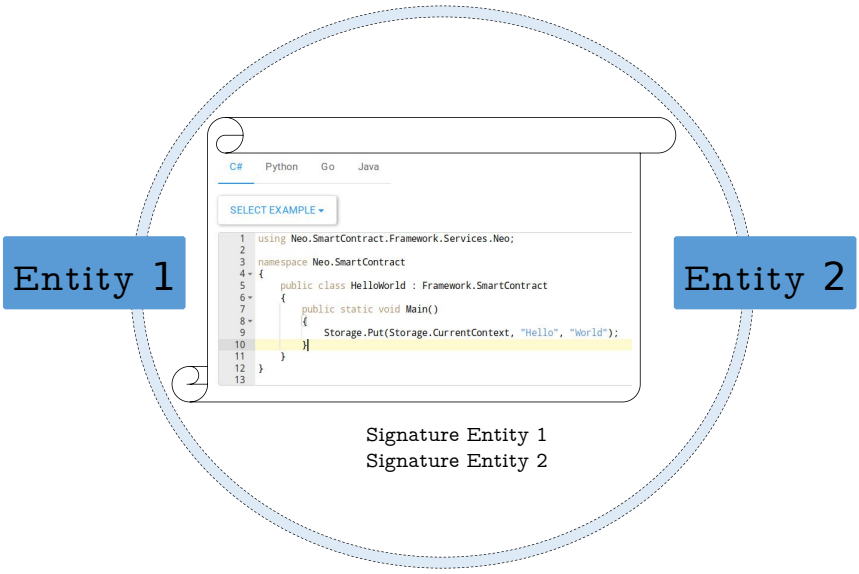

Fig. 2 Smart Contract example. Figure drawn by the authors.

The Smart Contract advantages are:

- Automatic and autonomous execution;
- Fast and direct;
- Safe and trustless execution;
- Avoid manual error;

- "Cheap", according to the application;
- Transparent and backup by default;
- Code is law.

Macrinici, Cartofeanu and Gao (2018) complements:

> "A key premise for contracts is that they represent a binding agreement between two or more parties, where every entity must fulfill their obligations according to the agreement. Another important element is that the agreement is enforceable by law, usually through a legal centralized entity (organization). However, smart contracts replace the trusted third parties; that is, the intermediaries between contract members." (p. 02) [20].

2.4 Digital Democracy

Applications that promote Democracy have a great potential for investments. In particular, Blockchain based solutions present good aspects related to citizens transparent interaction with public sectors [16]. In this sense, it becomes an alternative for democratic governance, since the government could share political informations, save and verify citizen identity, as well as other interesting applications. In addition, it has the potential of generating novel alternatives for a better citizens' participation in government decisions at the national, state and municipality levels. Also, improved voting systems can be designed based on blockchain [17].

Figure 3 illustrates an example of Digital Democracy, where citizens can be more participative in government decisions, for increasing citizens' rights and promoting inclusive participation. One can say that the democracy exists when citizens have equal rights.

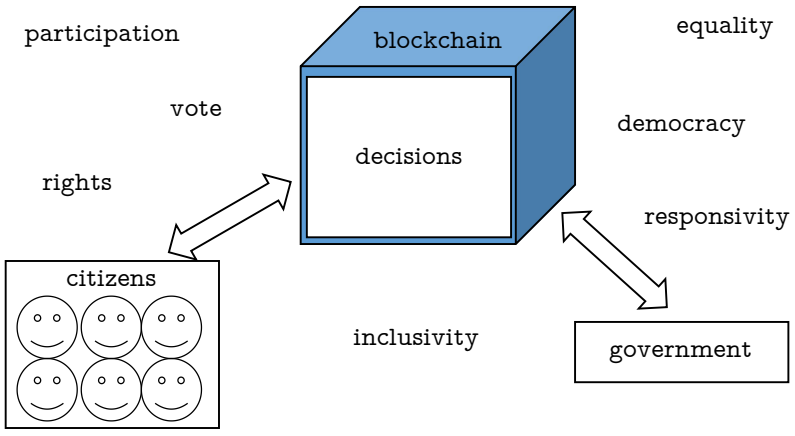

Fig. 3 Digital democracy.

3 Bibliometric search

By looking at the goal of understanding the relation between the terms explained in the Sections 2.1, 2.2, 2.3 and 2.4, a bibliometric search of keywords, in refereed world databases, is conducted. By using multiple databases it becomes possible to cover most part of the researches on the discussed topics [21].

In this sense, the following databases were considered (all of them accessed online on 28th of September, 2018.): Springer Link, SCOPUS, IEEExplore, Science Direct, Web of Science and Taylor & Francis Online. The bibliographic search shows the numbers of researchers done mentioning the selected keywords. The following keywords were combined and searched (Table 1 shows the obtained results):

1. Digital City (DC);
2. DC (Digital City) + Blockchain;
3. DC (Digital City) + Digital democracy;
4. DC (Digital City) + Smart contract;

	Keywords			
Database Search – 2018				
	DC	DC + Blockchain	DC + Digital democracy	DC + Smart contract
1. Springer Link	124.691	375	8.602	4.204
2. SCOPUS	130.482	260	10.584	895
3. IEEEXplore	9.730	17	7	4
4. Science Direct	110.570	174	2.116	2.377
5. Web of Science	5.209	4	0	0
5. Taylor & Francis Online	68.484	57	12.903	1.698

Table 1 Number of publications found in well-known databases.

The concept of DC is showing a high number of publications with pioneer studies dating back to the 90's [3], [4], [28], when the nomenclature and definition about a DC started to be uncovered and drawn. Both nomenclatures look for a city that attend citizens' necessities, promoting better life quality, urban development, mobility, and the search for an ideal/dreamed city [12], [27].

The E-government can be supported by the DC, in order that the Digital Government provides a virtual environment [5], [18]. According Anthopoulos and Tsoukalas (2016), "the Digital City's definition is extended to the global Information Environment, focusing on the needs of a city area." (p. 91) [5].

Bolívar (2015) complements that the DC concept incentives the government to use Information and Communication Technologies for promoting political participation. In this sense, the technology came to accomplish changes in different areas and in the government, to proportionate a transparent governance and look for political strategies, arising as a "smart governance" [10].

Finally, a voting system with blockchain can be inserted in the context of "smart governance", which breaks down some barriers and limitations of the current electronic voting system [17]. In this sense, the blockchain can be applied in different areas, as well as the smart contract tools together with smart governance. In the bibliometric search, the term presented the lowest number of publications, what is reasonable since it is an emerging technology along with the smart contract.

3.1 Terms popularity

In the sense of complementing the bibliometric search, Figure 4 was drawn from searchers done in the Google Trends (GT) platform. The GT is a Google's database that analyzes the popularity of some terms based on their private repository. In this system, it is possible to define the time period, local (country, region) and compare different terms.

The search was made between using the same labels chosen for the Bibliographic search presented in the last section. Results of a worldwide search from the last 3 years were considered (from 22 October 2015 to 22 October 2018).

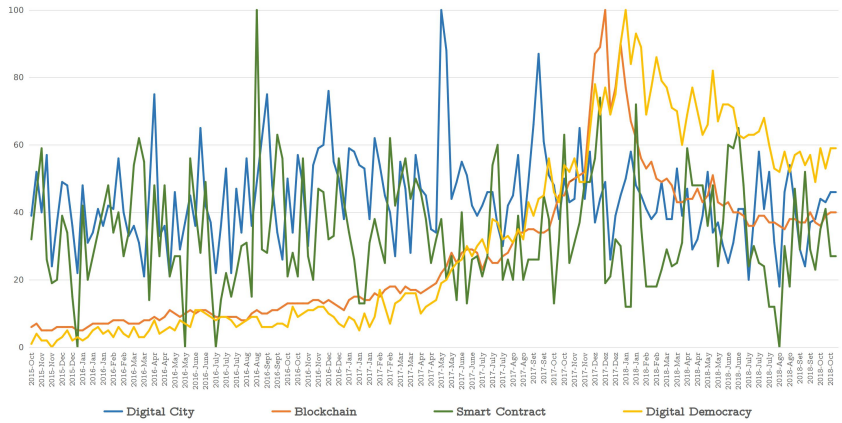

Fig. 4 Google Trends between the labels Blockchain x Digital Cities x Smart Contract in a 3 years interval

Table 2 analyzes the biggest and lowest peaks from each keywords search from the GT, By analyzing this numbers, it is possible to conclude that each label had a specific time of higher and lower demands. DC and Smart Contracts had constant peaks over the last 3 years, but the second one had more lowest peaks (only considering the year of 2016, the months of January, May and July can be highlighted as lowest peaks). On the other hand, DC remained without lowest peaks and presented

a higher peak on May 2017. Considering all searched labels, it is possible to affirm that the most stable period was between November 2017 to June 2018.

	Keywords			
	Google Trend Search			
	DC	Blockchain	Digital democracy	Smart contract
1. Higher Peak	2018-Jan	2017-Dec	2018-Jan	2016-Sept
2. Lower Peaks	2015-Nov	2015-Nov	2015-Nov	2015-Dec 2016-May/July

Table 2 Lowest and highest peaks of searching according to Google Trend from 22 October 2015 to 22 October 2018.

4 Conclusion and future works

Through the analysis of this study it was possible to conclude that the emerging technologies approached here (Blockchain, Smart Contract and Digital Democracy) complement each other and have an important impact on DC in order to provide better services and communication on the city. Beyond these technologies, it is noteworthy that IoT has an important contribution to DC, integrating the devices in the cities, as well as helping urban mobility.

While these novel technologies have been approaching the citizens, some of them might not be aware about it. In this sense, this chapter had also this whole of increasing awareness. It is expected that society will evolve into a system where citizens are more participative and have a better relationship with the government, in particular, with more efficient and transparent voting systems.

As a continuation of this study, a survey with citizens, with the purpose of comprehending concepts about DC, is proposed, which has the potential of pointing out what they agree about these new digital advances.

References

1. Ubiquitous cities in asia: a new concept of urban living. https://www.casaasia.eu/noticia/detalle/202459-ubiquitous-cities-in-asia-a-new-concept-of-urban-living. (Accessed on 07/15/2017)
2. Ahvenniemi, H., Huovila, A., Pinto-Seppä, I., Airaksinen, M.: What are the differences between sustainable and smart cities? Cities **60**, 234–245 (2017)
3. Anthopoulos, L.G.: Understanding the smart city domain: A literature review. In: Transforming city governments for successful smart cities, pp. 9–21. Springer (2015)

4. Anthopoulos, L.G., Gerogiannis, V.C., Fitsilis, P.: Supporting the solution selection for a digital city with a fuzzy-based approach. In: KMIS, pp. 355–358 (2011)
5. Anthopoulos, L.G., Tsoukalas, I.A.: The implementation model of a digital city. the case study of the digital city of trikala, greece: e-trikala. Journal of e-Government **2**(2), 91–109 (2006)
6. Anthopoulos, L.G., Vakali, A.: Urban planning and smart cities: Interrelations and reciprocities. In: The Future Internet Assembly, pp. 178–189. Springer (2012)
7. Barbosa, A.C., Oliveira, T.A., Coelho, V.N.: Cryptocurrencies for smart territories: an exploratory study. In: Proceedings of the IEE World Congress on Computational Intelligence (2018)
8. Batty, M.: The computable city. International Planning Studies **2**(2), 155–173 (1997)
9. Batty, M., Marshall, S.: Centenary paper: The evolution of cities: Geddes, abercrombie and the new physicalism. Town Planning Review **80**(6), 551–574 (2009)
10. Bolívar, M.P.R.: Smart cities: Big cities, complex governance? In: Transforming city governments for successful smart cities, pp. 1–7. Springer (2015)
11. Cicero, M.T.: De natura deorum libri tres, vol. 3 (1885)
12. Cocchia, A.: Smart and digital city: A systematic literature review. In: Smart city, pp. 13–43. Springer (2014)
13. Coelho, V.N., Oliveira, T.A., Coelho, I.M., Coelho, B.N., Fleming, P.J., Guimarães, F.G., Ramalhinho, H., Souza, M.J., Talbi, E.G., Lust, T.: Generic pareto local search metaheuristic for optimization of targeted offers in a bi-objective direct marketing campaign. Computers & Operations Research **78**, 578–587 (2017)
14. Coelho, V.N., Veloso, I.F.O., Oliveira, T.A., Coelho, V.N., Veloso, I., Veloso, V.M., Souza, M.J.F., Filho, A.F.S.: A multi-criteria view about judicial and legislative decision making in digital cities and societies (in portuguese). In: Proceedings of the XLIX Annual Brazilian Symposium on Operational Research, p. 3979 a 3989 (2017)
15. Darwin, C.: Evolution by natural selection. London: Nelson (1963)
16. Galen, D., Brand, N., Boucherle, L., Davis, R., Do, N., El Ba, B., Kimura, I., Wharton, K., Lee, J.: Blockchain for social impact, moving beyond the hype. Graduate School of Stanford Business – Center for Social Innovation (2018)
17. Hjalmarsson, F.P., Hreioarsson, G.K., Hamdaqa, M., Hjalmtysson, G.: Blockchain-based e-voting system. In: 2018 IEEE 11th International Conference on Cloud Computing (CLOUD), pp. 983–986. IEEE (2018)
18. Hsieh, P.H., Chen, W.S., Lo, C.J.: An investigation of leadership styles during adoption of e-government for an innovative city: Perspectives of taiwanese public servants. In: Transforming city governments for successful smart cities, pp. 163–180. Springer (2015)
19. LaPointe, C., Fishbane, L.: The blockchain ethical design framework (2018). URL http://www.sciencedirect.com/science/article/pii/S0736585318308013
20. Macrinici, D., Cartofeanu, C., Gao, S.: Smart contract applications within blockchain technology: A systematic mapping study. Telematics and Informatics (2018). DOI https://doi.org/10.1016/j.tele.2018.10.004. URL http://www.sciencedirect.com/science/article/pii/S0736585318308013
21. Mora, L., Bolici, R., Deakin, M.: The first two decades of smart-city research: A bibliometric analysis. Journal of Urban Technology **24**(1), 3–27 (2017)
22. Nam, T., Pardo, T.A.: Conceptualizing smart city with dimensions of technology, people, and institutions. In: Proceedings of the 12th annual international digital government research conference: digital government innovation in challenging times, pp. 282–291. ACM (2011)
23. Oliveira, T.A., Barbosa, A.C., Ramalhinho, H., Tavares, W., Oliver, M.: Citizens and information and communication technologies. In: Proceedings of the IEE World Congress on Computational Intelligence (2018)
24. Oliveira, T.A., Coelho, V.N., Ramalhinho, H., Souza, M.J., Coelho, B.N., Rezende, D.C., Coelho, I.M.: A vns approach for book marketing campaigns generated with quasi-bicliques probabilities. Electronic Notes in Discrete Mathematics **58**, 15–22 (2017)
25. Oliveira, T.A., Coelho, V.N., Tavares, W., Ramalhinho, H., Oliver, M.: Operational and digital challenges to connect citizens in smart cities (in portuguese). In: Proceedings of the XLIX Annual Brazilian Symposium on Operational Research, pp. 3819–3830 (2017)

26. Organization, I.S.: TSmart cities preliminary report 2014. (2014). URL http://www.iso.org/iso/smart_cities_report-jtc1.pdf
27. Trindade, E.P., Hinnig, M.P.F., Moreira da Costa, E., Marques, J., Bastos, R., Yigitcanlar, T.: Sustainable development of smart cities: A systematic review of the literature. Journal of Open Innovation: Technology, Market, and Complexity **3**(3), 11 (2017)
28. Wang, L., Wu, H., Song, H.: A framework of integrating digital city and eco-city. School of Business, Hubei University, Wuhan, China (2002)
29. Wright, A., De Filippi, P.: Decentralized blockchain technology and the rise of lex cryptographia (2015)

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Citizens and Information and Communication Technologies

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***Abstract*—Smart cities have been receiving great focus during the recent years. One important topic that it covers is the use of technologies to help the connection between smart cities and citizens. These links can influence different cities services and governance such as transport, politics, education, public transparency, citizens' rights, among others. Those services work much better when they are connected, interconnected, participative and transparent. Any kind of environment requires these improvements, both in underdeveloped and developed countries. In this sense, for this cultural and evolution process, it is important to understand how the citizens are responding to these technological stimulus. This work describes and investigates how these themes are treated in the literature, using bibliometric method and data from SCOPUS, Web of Science (WoS), IEEEXplore. In this study, discussions will be focused on the technological area, however, with efforts in reaching distinct strategical areas that are nowadays working side by side on it.**

I. Introduction

The technology comes as a tool to facilitate cities planning and management. Smart cities (SC) is the term that is being used in this work, but there are other nomenclatures that can be designated as the same phenomena, such as: digital, innovative, intelligent or creative cities, among others [1]. All these nomenclatures intended to refer to the idea of embeding current technologies in urban contexts, analogous to modern sustainability concepts.

As shown by Wolfram (2012) [2], it does not matter if 'smart cities' are labeled as 'digital cities' or vice versa, when searchers are done, the results are similar for both terms, because the two definitions are commons. One can conclude that both labels are looking for better city urban planning and development. Wolfram (2014) [3] reaffirms that the Information and Communication Technologies (ICT) and modern urban development walk side by side.

There are several definitions for the SC term, for the European Union Agency for Network and Information Security (ENISA) [4], "Smart Cities rely on ICT architecture to retrieve, process and exchange data (p. 6)". Different cities can nowadays easily share information and decisions between them. This partnership is plausible because one of the main objectives, for different cities, is to provide a flexible and good infrastructure for citizens. Furthermore, SC is a fuse of education, culture and business [5], as well as a "hybrid mix of social enterprise, cultural enterprise, and economic enterprise. [...] is a humane city that has multiple opportunities to exploit its human potential and lead a creative life." (p. 285)[6].

The new generation of devices are mostly embedded on Internet of Things (IoT) capabilities, being properly designed for working in a distributed fashion. Thus, suitable for being connected, and interconnected with citizens, promoting a participative environment. Since the pillars of this transition are settled in the development of new low-cost equipment, SC's are emerging in both developed and underdeveloped countries. However, the scale of these changes are different from place to place, according to private and public interests, cultural values, socioeconomic background and educational level. Therefore, it is relevant to highlight the context-dependency approach to SC initiatives, as there is no one-size-fits-all path. In this sense, one important point to be highlighted is transparency and security, since citizens want their privacy and also actively contribute to the society. Regarding this aspect, one important point to be highlighted is that at the same time citizens use more technologies they lose some privacy. A paradoxal trade-off. Usually as security increases it implies in less privacy [7] in the same time that the personal data becomes more visible. Castells (1999) [8] complements that the ICT is a tool for the invasion of privacy. In this paper, it will be commented, analyzed, described and interpreted the actual situation of the citizens and the technology received with data searched in important world databases as discussed in the abstract.

The ICT has the potential to improve decision makers and citizens relationships, making cities systems more digital and

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communicative. However, even with the advances in information and communication technologies, several challenges for engaging citizens in social decisions remain open [9].

Digital governance shows up as a fundamental tool for this connection, since it promotes a cognitive control of the citizen to the State. Chun et al. (2010, p. 2) [10] defend that "The citizens voices should be heard and reflected back to transform the existing government policies. In order to achieve this kind of transformation, there needs to be extensive technology support for citizen participation." On the other hand, well-designed urban planning associated with multi-criteria analysis regarding citizens goals and wishes related to cities services can guide a more sustainable evolution of society.

After passing through the introduction, it was possible to see the relations between the SC concept and various areas, as for example. This is because the SC major objective would be facilitate the planning, construction and intelligent services to the cities and their citizens. In addition, we highlight that citizens are an important point of discussions surroundings cities, it is also crucial to understand the challenges for the citizens to live with the technologies that are coming, knowledge that could improve society quality of life. By fostering efficiency at any cost, the levels of complexity may be quite hard to people handle. In order to highlight SC relevant concepts, in particular, this study tries to present statistics of publication in the scope of SC and various scenarios, involving different areas. In this sense, it explores the SC themes and the technological area, concepts which are merged with other important strategical areas, such as: social sciences, governance, human interactions, which are fundamental parts of this aforementioned cities evolution process. To achieve this goal, bibliometric methods [11] [12] were used in order to realize the search of keywords that was performed on the chosen database. The bibliometric research is an important scientific tool, based on quantitative analyses, it is a "[...] quantitative evaluation of publication and citation data" (p. 3) [11]. Along this insight, it will be possible to merge the themes and see how discussions about the technological development are being pointed out in the literature and in the industry. A main focus on different cities services, and how citizens are perceiving these tools, will be detailed. This paper will try to present an open view on the two mainstream subjects (SC and Citizens) aiming to provide a sociological perspective to the topic.

II. Motivation

The city becomes more important from the moment that urban population increase. Along with this growth, new strategies and technologies are being planned in order to proportionate a better life to the human kind. In this sense, addressing the studies that are being done to improve the cities' development becomes an essential and important point to bridge narratives and promote cohesion.

The motivation to realize this work is the potential that SC studies have today to impact on the society. As an interdisciplinary topic, it varies around many different perspectives, merging the technological and the social science areas. It is notorious that SC theme have been receiving great focus, from all around the world in the last years, even though the introduction of the theme was in the 90's. Probably, the result of these pioneers studies are being, nowadays, idealized and put into practical. In summary, materializing and building an era of technological innovation supported by novel business models and governance structures.

Along with this technological innovation, comes the way in which citizens see these changes and follow that development. It is not so easy to follow this technological progress, mainly with no instructions. When some technology comes to a city, or when some technology comes in order to make everyday life easier, the population needs high levels of education to use it. The same happened in the industry, the employees need training to learn how to use and work with new technologies, machines and equipments. Regarding this idea, the same happen with mobile devices, each year different modern mobile devices are launched. Typically, mobile companies make minor different changes from their previous released model, but this is sufficient to increase the product price for the personal use devices. In contrast with this position, its important to consider the interoperability [13] [14], that's the system capacity to communicate transparently with another system. For a system to be considered intoperable, it's important that it works with open standards or ontologies, and these kind of system does not only consider technology, but takes into account the human and institutional layer. On the other hand, human accumulated knowledge becomes much stronger and consolidated, facilitating the learn for those young generations. But, even nowadays there are people who don't know how to use some technologies.

Myers (1998) [15] showed, in his work, the earliest and most influential systems in human-computer interaction technology. He subdivided their evolution into different stages, such as: university research; corporate research; and commercial products. For gesture recognition, the text editing was firstly used in university researches in 1960. Then, 18 years latter used in corporate research and in 1980 for commercial products.

For example, the mouse was first used in 1965 and 5 years latter it was introduced for corporate research and, also, around 1980 for commercial products. In this sense, its possible to comment that some technologies are first approached and developed in university's researches then inserted in corporative research, becoming innovative commercial products. "In fact, virtually all off today's major interface styles and applications have been significantly influenced by research at universities and labs, often with government funding." (p. 52) [15]. New methodologies of Research and Development (R&D) have been developed to attend the real population necessities, in order to insert in this today's competitive market [16], innovations that will attend citizens necessities could use Living Lab technology that " [...] represents a user-centric research methodology for sensing, prototyping, validating and refining complex solutions in multiple and evolving real life

contexts. (p.4)" [17].

As it was previously questioned, regarding how the citizens use some technologies, first the technology starts to be studied within academic institutions and then in the commercial area, besides this, it is notoriously important the government investments to "explain" and guide citizens about its use. In this sense, government investments, for the university to conduct research [15], should be highlighted as important investments to society. Carayannis and Campbell (2009) [18] defend a methodology that's understand the importance of investing in academia to generate broad-based sustainable development, "Triple Helix is very powerful in describing and explaining the helices dynamics of university-industry-government relations that drives knowledge and innovation in the gloCal knowledge economy and society. " (p. 2018) [18].

III. Database search cities and citizens studies

Bibliometrics searches are used to investigate the conceptions in the literature in order to explore the development of some theme [12]. In order to perform and merge the SC conception, some key words were chosen to be used in the search. It was realized in three international databases, namely: SCOPUS, Web of Science and IEEEXplore. The SCOPUS and Web of Science were chosen because represents two of the bigger, attractive, attractive and frequently-used search tools in academia to track impact factor [19], [20]. The IEEExplore was chosen because the most part of publication are related to engineering and robotics area [21]. These three databases will give essential data to realize the work. The Google Scholar platform wasn't chosen because it is a platform that search works on a certain topic, and doesn't track article impact factor. Which, in future works, could be used, since impact factors is also a metric that is currently under several discussions. According to Mora et al. (2017, p. 6) [12], "the use of multiple databases made it possible to conduct a comprehensive interdisciplinary search and broaden the field of investigation, avoiding the risk of not capturing the full extent of research on smart cities." These documents searchers represents all the SC literature published since the first indication of study in this area, 1972 (considering all content of manuscripts), including title, abstract and all fields of research in each area of the key word.

Initially, the search was done with the SC keyword and then mixtures of SC studies with other areas, the result will be present on Table I. The following combinations were considered:

1) SC (Smart city or Smart Cities);
2) SC (Smart city or Smart Cities) + (Operations Research or Operational Research);
3) SC (Smart city or Smart Cities) + Citizens;
4) SC (Smart city or Smart Cities) + (IoT or Internet of Things);
5) SC (Smart city or Smart Cities) + (E-governance or e-government or cyber government);
6) SC (Smart city or Smart Cities) + Democracy;
7) SC (Smart city or Smart Cities) + (Social Participation or Social Science);
8) SC (Smart city or Smart Cities) + ICT (Information and Communication Technologies);
9) SC (Smart city or Smart Cities) + Human Interactions;
10) SC (Smart city or Smart Cities) + Technology.

After completing the search, the Table I could be drawn, which shows the results obtained for each performed search, considering information available in the three databases until January, 2018. Obviously, the number of publications with SC term, in all databases, represents the largest number of searches compared with others restricted searchers. As Mora et al. (2017) [12] concluded, the publications in SC from 1992 to 2015 increased 600 times over 24 years. However, his search was done using Google Scholar. As it is possible to see, nowadays SC are a well approached subject in the world, in the TV news, web, science, industry, among others.

The first studies in this area were more correlated with technology, but, it is possible to verify the concern to mention the SC with the citizens, as well as with modern governance (namely digital governance) and social participation. This is mainly justified by urban growth, which is being approach in this work. It's possible to analyze that some themes such as "SC + (e-governance) or (democracy) or (citizens)" are gaining ground in recent researches, because some technologies started first in the university research and corporate in the 50's decade [15]. Therefore, when this technology come to the population, new strategies and government investments are necessary.

In order to verify in which areas scientific works are being performed and published, pie charts generated with the accumulated sum of publications, in two different years, are depicted in Figure 1. The slices indicates which areas SC researches are publishing and working on. The chart in the right was fulfilled in January 2017 while the left chart in January 2018. These graphs present a comparison of one year difference in order to highlight the evolution of the term regarding different perspectives and focus. It's possible to analyze, through Figure 1, that most part of publications done in 2017 were in the computer science area, followed by engineering and social science areas, among others. In comparison with one year difference, in 2018, these three areas continue with the majority of studies, but with half of the amount.

The Table I shows some precise numbers that were found. Depicted values represent the number of publications in each search for a specific database. As mentioned, it can be verified (looking at columns with labels (1), (4), (8) and (10)) that the most part of publication are in the SC themes with technological ones. The SC + Social Science (7) key-words combination have been growing in the last years and represents a considerable number of works. It's clear that the key words combinations of columns (5) and (6) are emerging in the SC theme, merging the technological area and the social science one. In order to analyze the sum publications in these three databases, the last row was included.

The SC theme has been winning space in different research

	Keywords									
	Database Search – 2018									
	(1) SC	(2) SC + OR	(3) SC + Citizens	(4) SC + IoT	(5) SC + E-governance	(6) SC + Democracy	(7) SC + Social Science	(8) SC + ICT	(9) SC + Human Interactions	(10) SC + Technology
1. Web of Science	7.474	201	978	1.207	128	29	224	679	146	2.695
2. SCOPUS	81.740	5.149	8.173	8.181	2.055	6.001	28.653	21.103	12.242	52.308
3. IEEEXplore	8.318	9.411	4.907	11.668	193	557	11.934	31.030	10.539	44.268
TOTAL	97.532	14.761	14.058	21.056	2.376	6.587	40.811	52.812	23.109	99.271

TABLE I: Key-words searched in different databases, Jan. 18.

areas and also can been seen that this theme is being handled by other areas, such as medicine, energy, thought others. The growth of publications in the social science area in one year (Figure 1, may be due to the citizens' awareness of their rights about the technology use.

Two pairs of key-words combination were picked in order to illustrate the relationship between the below described topics:

1) SC (Smart city or Smart Cities) + Human Interactions;
2) SC (Smart city or Smart Cities) + Technology.

The Figure 2 was generated using the Software R, v3.2.3, and package ggplot. It shows the cumulative sum of publications from 1992 to January 2018. SC concepts have, at least, twenty years life and still in progress. However, the year of 1992 was chosen because it marks a moment when the first mentions started to appear in the scientific area, while, as already mentioned, the label "smart" was introduced, around 1994 [22].

The Figure 2 shows the comparative of publications with the cumulative sum of publications of key-words "SC and Human Interactions", with the color red, and the cumulative sum of publications of "SC and Technology", in blue. By comparing these lines, it is feasible to verify that the publications in "Human Interactions" have a less accumulated sum of publications than those that mention the key-word "Technology". While the first one has 12.500 publications the second one has 50.000 publications. It sounds reasonable, since the first term could also be a stream of technology. This is due to the fact that the theme of SC and social science has taken shape in recent years, as was also justified at the years comparison presented at the Figure 1. The technology theme has been linked to SC since the concept emerged, thus, in the sense, the initial studies about SC were at the most part related with technologies and, specifically, computer science [12]. That is why it has a higher parcel of publications. Even citizens being the focus of smart cities, technology is fundamental to its conceptualization, thus, these founded values are concise.

As it was approached here, the number of searchers in different areas about SC grown up along these last years. However, according to Mora et al. (2017) [12], cities are organized systems that require a challenge to merge social and technological areas, to improve the urban planning with life quality and social aspects. Batty (2013) [23] complements that the ICT are tools that gave a positive scenario for the new urban planning science and new science of cities, planning support systems, urban computing. Many studies are taking place in different areas related to SC, this could be seeing by different areas that are now working together, as can be verified in the graph of Figure 2. Finally, it's possible to analyze that the number of publications has been increasing significantly over the years, and until nowadays it covers different strategical areas.

IV. Citizens and Information and Communication Technologies

The citizens' cultural evolution process has its roots with the rural-urban migration [24], owing to the fact that population original area started to change and the life there began to be uninteresting [25], as can be highlighted: "where previous modes of work and social life have become unviable or unattractive, and because the awareness of better opportunities elsewhere. Emigration often arises through development and social transformation." (p. 69) [25]. Thus, Castels et al. (1999) [8] affirms that it is necessary to reverse the population exclusion, and the ICT needs to serve for empower humanity and "Require massive technological upgrading of countries, firms and households around the world." (p. 4) [8]. In this sense, the central objective of the ICT is to stimulate the world development, providing tools for economic growth by modernizing production systems. SC concept has played an important role in academic and industry fields [26]. So, it's important to arouse the interest of the population and the businesses/companies in order to realize investments and guide technological progress. As the ICT seems a prerequisite for global economic and social development.

Thus, after characterizing this cultural evolution process and explaining the importance of ICT for it, as responsible for technological and economic development, this process should cover the use of technologies by the population. For example, as in the elections, when the technology come to facilitate the voting system. We can see that the coordinators are starting making this type of inclusion, which are in the scope of smart governance strategies, inside the core of ICT innovation [27], [28].

When these technologies come, how will the population receives and interacts with it? According to Scheufele and Lewenstein (2005) [29], the population form opinions even without relevant scientific information, usually they are influenced by the mass media. At the time the population move from their original rural area, they need to learn and get used to new ways of living in an urban place. The industry follows

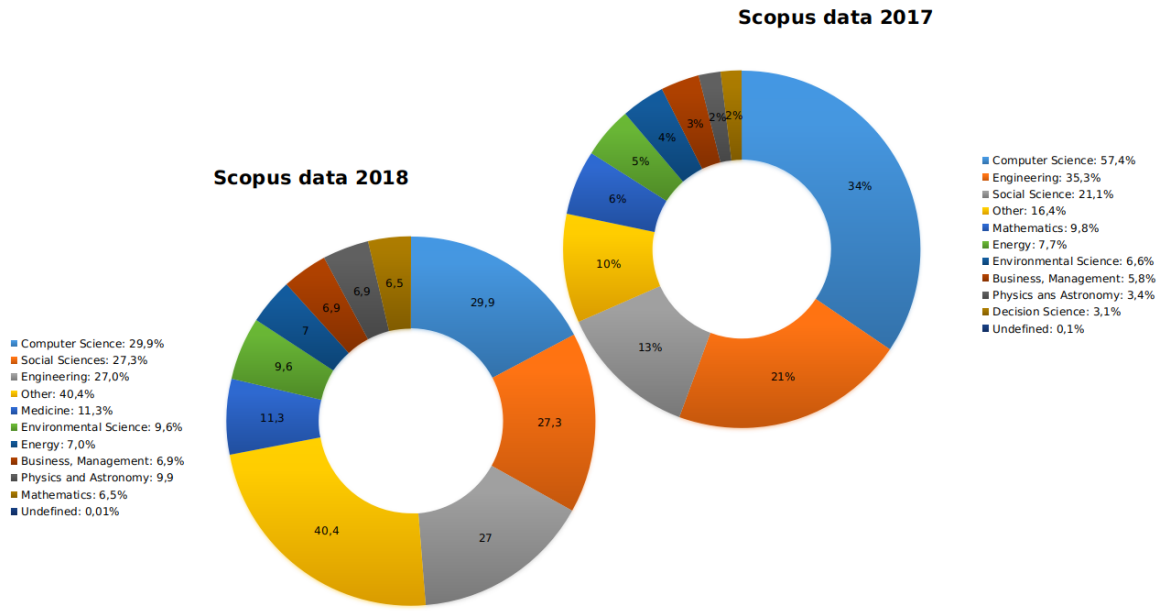

Fig. 1: Figure extracted from Scopus database, result of a search with the terms: “Smart City”, at January 31th, 2018.

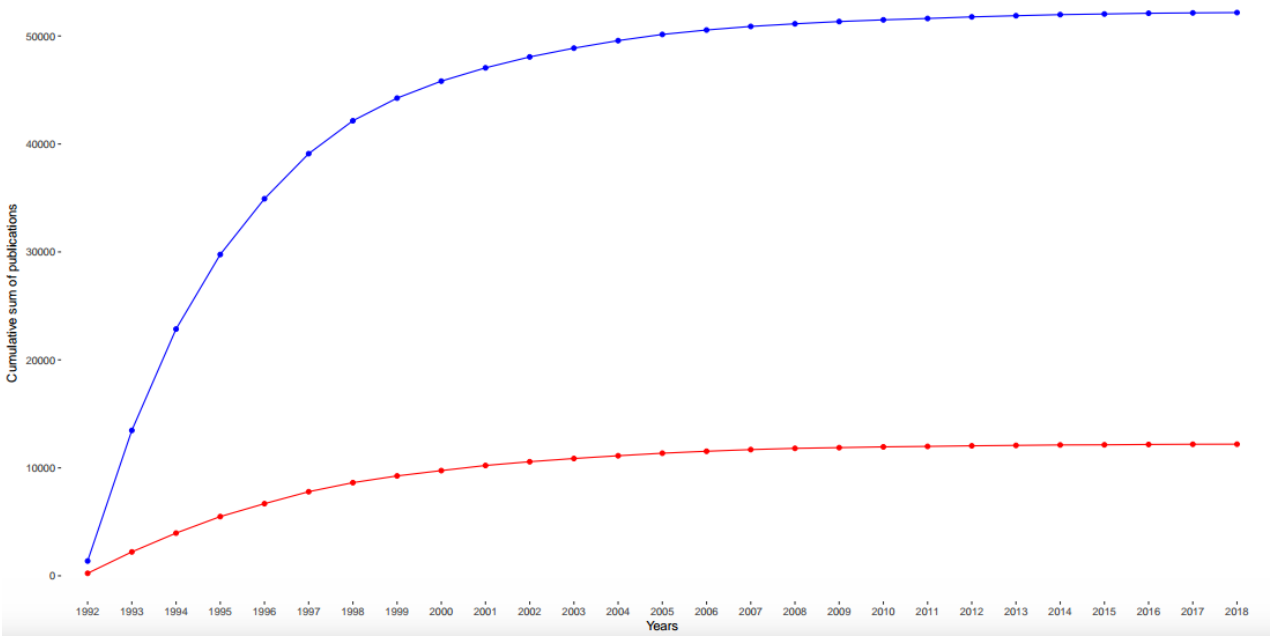

Fig. 2: Generated at R with the cumulative sum of years, for the term Smart City and Human Interactions (red) and Smart City and Technology (blue).

the technological development and search for employees and specific trained persons to work on it. On the other hand, in some cases, citizens start to work at the industry/company and receive training to get sufficient information and knowledge. How it was approached in the Session II, it is important governmental investment in order to give the residents the correct instruction for using novel technologies, devices and services. For instance, IBM [30] defends that smart governance will combine the economic and societal systems dynamically with citizens, "communities, and businesses in real time to spark growth, innovation, and progress" (p. 287) [6]. And "Over the years, smart cities have become the symbol of ICT-driven urban innovation and development and have attracted the increasing attention of 2ers from universities, governments, and businesses." (p.4) [12]. The larger continent to contribute for the SC growth and urban development is Europe, because it has the greater scientific impact publications about the theme (52 percent) [12].

Wolfram (2012) [2] points an important ICT use, "the informatization of society" for aggregating the use of selected ICT solutions including social or individual practices and public or private organization. As mentioned, "Especially in urban contexts, new networked ICT usages are thus becoming self-evident parts of everyday practices in both professional and private milieus;" (p. 2) [2], ICT is becoming a common decentralized option chosen by industry and society.

In summary, the ICT introduction in a city is responsible for integrating systems, as a smart government [6] that is a crucial component of a smart city. In summary, the ICT has many tools to connect the citizens with the cities and to facilitate this relation, including: better urban living and innovation; smart government, with efficient features; clear governance; smart governance; better urban living; greater citizen participation, among others.

V. Final consideration and future works

This paper has presented a bibliometric search about SC theme with the citizens and ICT in focus. At our present time, there is not an exact model what a SC is [31] [32]. There are many kinds of SC concepts and current implementations that make use of some indicators addressed in this work. Most of them merge ICT, smart government, OR and social interactions, as highlighted along this study. With one year difference, it was possible to verify an increase of publications in different areas, reaffirming the interdisciplinarity of the theme. In particular, this increase was highlighted in the field of social sciences, in which studies focused on social development and citizens awareness are appearing. The SC merge so many areas to make a better urban environment using the ICT tools to connect citizens and technology.

By reading this brief literature oriented study, one could possibly have an insight about the importance of the citizens into the SC urban development, the city needs to offer the same social participation rights to the whole population. In this sense, it's possible to analyze many important points that are been used to make better environments of coexistence and civilization. It was possible to see that the technological area is being related with the social one, representing social integration progress.

For future research, in order to go deeper into other well-known databases and system, we plan to make a search on twitter, reddit and google trends to achieve better comprehension about how the citizens think about the aforementioned evolution process. This additional analyses could make possible to understand, in real-time, citizens' opinion about these themes. Real-time in the sense of capture the ideas frequently posted in these other platforms and databases. It is expected that, in these databases, the citizens express their opinions. This task could be done in order to search about situations faced in different parts of the world.

Focusing on continuing this mix between social area and technology, next studies will explore the challenges for connecting citizens and smart city into the scope of ICT. Other tools could be used to show the results of the next works, such as with VOS viewer (visualizing scientific landscapes) and statistical analyzes. In addition, we will try to suggest improvements to the citizens and cities relation by considering the application of questionnaires and other types of analyses.

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References

[1] M. P. Rodríguez-Bolívar, "Transforming city governments for successful smart cities," *New York: Springer. doi*, vol. 10, pp. 978–3, 2015.

[2] M. Wolfram, *Deconstructing smart cities: an intertextual reading of concepts and practices for integrated urban and ICT development*. na, 2012.

[3] A. DAuria, M. Tregua, and F. Bifulco, "From digital city to smart city: different perspectives overlapping or misinterpreted?" in *Proceedings in GV-Global Virtual Conference*, no. 1, 2014.

[4] e. a. Cédric, "Iot and smart infrastructures: Smart cities," https://www.enisa.europa.eu/topics/iot-and-smart-infrastructures/smart-cities, 2015, (Accessed on 07/15/2017).

[5] L. Bartlett, "Smart city: Social entrepreneurship and community engagement in a rural regional city," in *Proceedings of the International Conference on Engaging Communities*, 2005, pp. 14–17.

[6] T. Nam and T. A. Pardo, "Conceptualizing smart city with dimensions of technology, people, and institutions," in *Proceedings of the 12th annual international digital government research conference: digital government innovation in challenging times*. ACM, 2011, pp. 282–291.

[7] L. van Zoonen, "Privacy concerns in smart cities," *Government Information Quarterly*, vol. 33, no. 3, pp. 472–480, 2016.

[8] M. Castells *et al.*, *Information technology, globalization and social development*. United Nations Research Institute for Social Development Geneva, 1999, vol. 114.

[9] T. A. Oliveira, V. N. Coelho, W. Tavares, H. Ramalhinho, and M. Oliver, "Desafios operacionais e digitais para conectar cidados em cidades inteligentes," in *Proceedings of the XLIX Annual Brazilian Symposium on Operational Research*, 2017, pp. 3819–3830.

[10] S. Chun, S. Shulman, R. Sandoval, and E. Hovy, "Government 2.0: Making connections between citizens, data and government," *Information Polity*, vol. 15, no. 1, 2, pp. 1–9, 2010.

[11] T. REUTERS, "Whitepaper using bibliometrics: A guide to evaluating research performance with citation data. 2008," vol. 20, no. 10, 2014.
[12] L. Mora, R. Bolici, and M. Deakin, "The first two decades of smart-city research: A bibliometric analysis," *Journal of Urban Technology*, vol. 24, no. 1, pp. 3–27, 2017.
[13] F. W. Neiva, J. M. N. David, R. Braga, and F. Campos, "Towards pragmatic interoperability to support collaboration: A systematic review and mapping of the literature," *Information and Software Technology*, vol. 72, pp. 137–150, 2016.
[14] R. Macrorie, S. Marvin, R. Raven, and A. Smith, "Standardising the smart city: Technical interoperability or computational governance?" 2017.
[15] B. A. Myers, "A brief history of human-computer interaction technology," *interactions*, vol. 5, no. 2, pp. 44–54, 1998.
[16] S. Leminen, M. Westerlund, and A.-G. Nyström, "Living labs as open-innovation networks," *Technology Innovation Management Review*, vol. 2, no. 9, 2012.
[17] M. Eriksson, V.-P. Niitamo, and S. Kulkki, "State-of-the-art in utilizing living labs approach to user-centric ict innovation-a european approach," *Lulea: Center for Distance-spanning Technology. Lulea University of Technology Sweden: Lulea*, 2005.
[18] E. G. Carayannis and D. F. Campbell, "'mode 3'and'quadruple helix': toward a 21st century fractal innovation ecosystem," *International journal of technology management*, vol. 46, no. 3-4, pp. 201–234, 2009.
[19] L. I. Meho and K. Yang, "A new era in citation and bibliometric analyses: Web of science, scopus, and google scholar," *arXiv preprint cs/0612132*, 2006.
[20] A. Aghaei Chadegani, H. Salehi, M. Yunus, H. Farhadi, M. Fooladi, M. Farhadi, and N. Ale Ebrahim, "A comparison between two main academic literature collections: Web of science and scopus databases," 2013.
[21] N. F. Lepora, P. Verschure, and T. J. Prescott, "The state of the art in biomimetics," *Bioinspiration & biomimetics*, vol. 8, no. 1, p. 013001, 2013.
[22] R. Dameri and A. Cocchia, "Smart city and digital city: twenty years of terminology evolution," in *X Conference of the Italian Chapter of AIS, ITAIS*, 2013, pp. 1–8.
[23] M. Batty, "Big data, smart cities and city planning," *Dialogues in Human Geography*, vol. 3, no. 3, pp. 274–279, 2013.
[24] P. Harrison, "Inside the third world: The anatomy of poverty," 1981.
[25] S. Castles, H. De Haas, and M. J. Miller, *The age of migration: International population movements in the modern world*. Palgrave Macmillan, 2013.
[26] R. Petrolo, V. Loscri, and N. Mitton, "Towards a smart city based on cloud of things, a survey on the smart city vision and paradigms," *Transactions on Emerging Telecommunications Technologies*, vol. 28, no. 1, 2017.
[27] N. David, J. Justice, and J. G. McNutt, "Smart cities are transparent cities: The role of fiscal transparency in smart city governance," in *Transforming City Governments for Successful Smart Cities*. Springer, 2015, pp. 69–86.
[28] V. N. Coelho, I. F. O. Veloso, T. A. Oliveira, V. N. Coelho, I. Veloso, V. M. Veloso, M. J. F. Souza, and A. F. S. Filho, "Uma visão multicritério para julgamentos em cidades e sociedades inteligentes," in *Proceedings of the XLIX Annual Brazilian Symposium on Operational Research*, 2017, p. 3979 a 3989.
[29] D. A. Scheufele and B. V. Lewenstein, "The public and nanotechnology: How citizens make sense of emerging technologies," *Journal of Nanoparticle Research*, vol. 7, no. 6, pp. 659–667, 2005.
[30] IBM. (2010). [Online]. Available: http://www.ibm.com/smarterplanet/global/files/us-en-us-l oud-ibmlbn0041-transtasman-book.pdf
[31] C. Moreno, "Desarrollo de un modelo de evaluación de ciudades basado en el concepto de ciudad inteligente (smart city)," Ph.D. dissertation, PhD thesis. Universidad Politécnica de Madrid, 2015.
[32] P. Neirotti, A. De Marco, A. C. Cagliano, G. Mangano, and F. Scorrano, "Current trends in smart city initiatives: Some stylised facts," *Cities*, vol. 38, pp. 25–36, 2014.

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Cryptocurrencies for Smart Territories: an exploratory study

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***Abstract*—The smart city debate will still be the scope of business, policy-making and territorial planning in the following years. Based on that, the paper aims to propose an interdisciplinary conceptualization of smart territories. The goal is to promote the contrary movement of megacities creation and also consolidate the geographical aspect of smartness. The concept was formulated based on the elements of sustainable territorial development, strategic spatial planning and smart governance. In addition, taking hand of a parallel literature review, the study explores the potential of creating complementary cryptocurrencies as a strategy of territorial planning. This term was built based on already existing complementary currency systems in distributed ledger technologies scope. The idea provided presents a great potential for poverty alleviation by bringing together financial and digital inclusion.**

I. Introduction

The phenomenon of Smart Cities has been adopted by a large number of disciplines, both in the academia and in the public and private sectors. These initiatives are commonly represented through multistakeholder models of governance [1], as a consolidated transversal field.

Considering the territorial dimension of these systems, it is crucial to place the smart governance as the pivot. Furthermore, it is also in order to encourage the opposite movement of urban migration in a growing population scenario. Another goal is to contribute to a sustainable digital transformation, thus that is the reason why this paper proposes a new understanding of smart territories. The point is that this term has been poorly adopted in the literature and there is a lack of involvement of territory experts on its use so far. A strategic analysis to this digitalization of the territory as a process becomes quite relevant.

The concept proposed is based on the issues of sustainable territorial development (context-dependency importance, autonomy and the activation of territoriality), the strategic spatial planning (frameworks for action aiming the balance between the communicative and instrumental rationality) and the emphasis on smart governance (role of guiding all the other sectoral elements of a smart city or territory).

The paper also aims to promote the consolidation of the distributed ledger technologies [2][3] in the scope of smart territories. It is relevant to mention here that blockchain technology is prompted as a major facilitator for the scalability of Internet of Things devices [4]. For that, and based on the action-oriented approach of the strategic planning, an assessment of the role of the complementary currencies systems may play in the near future is provided. In addition, this exploratory study intends to guide the future research on the potential implementation of complementary cryptocurrencies as a mechanism of sustainable territorial planning. This by a governance structure that aggregates different disciplines with the objective of contributing for a positive impact of modern technologies on society and space.

II. From Smart Cities to Smart Territories

A. Smart Territories: why another buzzword?

The first step is to state that the smart city term has become an urban label during the last years and as such it tends to be used in order to benefit some specific agendas. On the other hand, these buzzwords are important to bridge narratives, definitions and critics. Based on that, the related field has been even more transformed into an interdisciplinary one, with rising acceptance from regional and urban planners, policy-makers and social scientists.

Even though several critics have been made to the smart cities ecosystem, the terminology yet presents a broad perspective and will be in the core of businesses and policy-making in the following years. Furthermore, it is relevant to mention the tendency of social scientists towards debates of tangible and inclusive approaches, avoiding the pure critic.

With this regards, in this paper, the idea of smart territory is supported in a way to contribute for the following objectives: promote a more comprehensive vision of the impact of novel digital technologies (CI, IoT, DLT, ICT) in the society and space. Promote the opposite movement to the formation of massive and unsustainable urban centers. Promote the absolute development of territories (win-win solutions and less harmful

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trade-offs) rather than the relative local development. Consolidate the geographical aspect and support the development of user-centered technical solutions.

B. From the Local Development to the Sustainable Territorial Development

The concept of local development, that drove the creation of the sustainable territorial development, became mainstream in parallel with the rise of the smart city. Both in a globalization scenario. In addition, development must be understood as the increase in individual capacities. In a territorial perspective, it is the process of activating the territoriality of a place. That is, a collective action of inclusive uses and cooperative strategies [5]. It is the link of the territory and the society, the mediation of the territorial fixed assets and its social actions in an illustrative, functional and intellective way [6]. Territorial development (TD) is about increasing and controlling the complexity of a place.

The TD covers in its principles the decentralization of governance and policies, although emphasizing the social, economical, institutional and cultural dynamics of a specific context. Recognizing these differences from one place to another is a key factor in the promotion of actions for an inclusive and comprehensive program. The way a community reacts to external influences, such as modern technologies or supra-local policies, is mutable and it is based on the principles and values of the given territory. Thus, the way an individual perceives development (if it is "appropriate", "well succeed", "good" or "bad") relies on a cultural background, politically determined that influences social values and principles in a time period [6].

Based on this approach an in-depth territorial analysis can substantially contribute to promote local and regional development in a decentralized systems paradigm. Moreover, several tools can facilitate this process such as the Sustainable Livelihood Approach (SLA) or the Sviluppo Locale Territoriale (SloT), among others. They are similar in the issues of analyzing the local actors and their power relations, the territorial capital, as well as the political limitations and possibilities of action. It is noteworthy mentioning that sociotechnical systems analysis may play an important role in the use of technological innovations and public relations as well [7].

C. From the Collaborative planning to the Strategic Spatial Planning

According to Patsy Healey [8], a specialist in planning theory and practice, collaborative planning is described as participative and inclusive governance processes that orients spatial transformations. It is the process of allowing and enabling stakeholders to involve in the decision-making process through a shared control and responsibility over development initiatives. Hence entailing win-win multidimensional solutions [9].

This model of planning emerged as a critic to the rational comprehensive and political economy ones and is based on the communicative rationality in which the vision is constructed through trust-based relations by actions in a short period of time [10]. Trust is associated with social proximity established due to the geographical (physical) proximity [11]. In this sense, the digital proximity may facilitate and enhance the network, but it is not enough for establishing an homogeneous and genuine shared vision [12]. Nevertheless, collaborative planning and budgeting can guide the allocation of resources in a multi-scale perspective that takes the social dimension as priority and can be sustained by e-participation [13]. Following this reasoning, it may be seen that decisions are complex and may involve different goals.

In the role of CI, optimization methods are important techniques that assist decision makers to reach efficient strategic spatial planning [14]. On the other hand, as mentioned before, efficiency and trust are measures that can be seen from different perspectives. Then, systems may evolve to optimize different goals which is, usually, a hard task that should be reached throughout a consensus. While negotiation protocols are considerably evolving in the field of multi-agent systems [15], they are rarely applied in real social decisions.

There are several stages in the planning process that public participation can be conducted. Such as the problem identification, the socio-spatial context, the goals and objectives, desired outcomes and the legitimization of the proposed policies through cohesion and consensus-building. However, this paradigm of planning has been criticized with regards to political and professional rationality as well as in driving long-term development. Furthermore, the success of decision relies on their effects in transforming conflicts by guaranteeing rationality [16]. In addition, a big variety of actors playing a direct role on the decision-making process is crucial for such achievement [17].

Strategic spatial planning is an important alternative to counter-balance the limits of collaborative planning. Albrechts[10] argues that strategic spatial planning is a public process that aggregates different perspectives based on scientific knowledge, collaboration and socio-spatial interactions that builds a comprehensive frame for the development of a territory. In addition, this planning approach is based on a limited number of issues, taking into account the social, cultural and political aspects of the context. This approach fosters multi-level governance and diversity of actors in the planning processes. It is also about creating new forms of understanding the socio-spatial dynamics. Moreover, the transparency and accountability of institutions are key issues that may enable an effective inclusiveness, eliminating uneven power structures. More recently this paradigm of planning has been associated with the "performance school", that affirms that strategic spatial planning is about a normative (what should prevail); and epistemic (based on the effect of a project, program or policy) consensus [18].

The definition of Healey [19] for strategic spatial planning illustrates the issue assessed in this paper. She states that it is *"A social process through which a range of people in diverse institutional relations and positions come together to design plan-making processes and develop contents and strategies for*

the management of spatial change. This process generates not merely formal outputs in terms of policy and project proposals, but a decision framework that may influence relevant parties in their future investment and regulation activities. It may also generate ways of understanding of building agreement, of organizing and mobilizing to influence in political arenas."

This rationale could be interpreted as the combination of top-down and bottom up approaches for planning. One that is both scientific-oriented and community-based.

D. Smart Governance as the pivot

Smart Governance is one of the pillars of the broad concept of smart cities, nonetheless it is considered the main pillar due to its comprehensiveness and role in coordinating the other sectoral factors. It is commonly agreed that some elements are crucial conceptualizing smart governance, such as the use of ICTs, collaboration and participation from non government institutions (basic principle of governance), electronic administration, institutional cohesion, efficient decision-making and the outcomes are often related to social inclusion, accessibility to public services, transparency and economic development.

The term has gained importance in a conjuncture where the e-government and e-administration have been scaled up from the institution [20] to a territorial level. In parallel, urban governance experts have been adopting the use of technologies, mainly of communication and information, to enhance and facilitate the comprehension of urban systems [21]. With regards to smart cities initiatives, there are some concerns both up to the extent to which governments have the technological competence to handle negotiations and planning in a data-driven.

Smart cities projects are commonly implemented through a triple helix partnership, through agreements between representatives of the public sector, the industry and the academia [22]. The first through the regulation, policy-making and investments towards digitalization of urban systems [23]. The second mainly through the physical and digital capital due to its control of modern technologies sector and its particular interest in innovation and entrepreneurship. Finally, the latter contributes mainly through the knowledge capital in a mutual perspective where the academia provides and tests the most recent technologies (e.g. network, sensing and monitoring) and gathers incentives to validate theories in real-life scenarios through the living labs and testbeds [24]. The matter is that such initiatives usually are handled during pro-economic growth political conjuncture, which tends to limit to it the approach of development and may compromise current and future generations. Nonetheless, progressive-led parties still present reluctance to be pioneers in such projects, even though the smart city trend being an unavoidable phenomenon.

Technology itself will not solve all societal problems, however political understanding of it is fundamental for the development of smart sustainable cities [25]. Additionally, if indeed these implementations strategically tackle urban challenges, there would be no reason to be against the smart city trend. For example the cases of Amsterdam, Helsinki and Eindhoven, where the citizens not only interact with digital platforms, or are benefited by automated services, but carry responsibility in planning, monitoring and managing the city. These cities embrace other more comprehensive models of smart governance. One of those is the quadruple helix which adds the citizen dimension to the same level of participation as the public sector, the academy and the industry. The citizen dimension is subdivided into a media-based citizen (social network and communication) and a culture-based citizen (principles, values, traditions). Moreover, there are an even more comprehensive and non-anthropocentric view, the quintuple helix approach proposed by Carayannis *et al.* [26]. In this governance model the natural capital is placed as a key stakeholder. The contribution of Meijer and Bolivar [1] through a comprehensive literature review showed that there are four mainstream conceptualizations of smart governance:

- Government of a smart city: in this sense, smart governance is about the ability of public institutions to develop and implement effective policies that promote smart city initiatives.
- Smart decision-making: it is related to process of decision-making itself. Thus smart governance represents the efficiency in taking decisions through the use of network technologies, enabling a greater degree of rationality by government.
- Smart administration: could be understood as a new form of e-government that use diverse technologies to integrate different departments of the public institutions and their services. An internal institutional transformation.
- Smart Urban Collaboration (SUC): it is the one which demands the higher level of institutional change and inter-cross-operability. It is about the transformation of both the government and external organizations, such as the private sector and the civil society.

There is a common agreement in the literature that governments are key elements to promote smart cities [27]. Although it is relevant to highlight that a consolidated structure of collaboration between different stakeholders is crucial to solve problems of society, this goes beyond the elaboration and implementation of public policies. In this regard, the idea of Smart Urban Collaboration (SUC) foments the open dialogue through a platform that enables actors sentence interaction and articulation of interests, ideas, initiatives and values. Consequently it generates conflicts that can be transformed into opportunities through effective planning and management.

These more holistic approaches which require more institutional transformation rather conservation, conversely, not singularly are more effective for smarter cities. However, if the smart cities are used in a broader sense (involving issues such as smart living, smart economy, smart mobility, smart environment and smart people), this model of smart governance would be fundamental for the near future sustainable development of territories. Moreover, empirical research are needed for in-depth analysis to combine collaborative governance and smart governance.

Finally, smart governance is about a modern way of governing a city that covers platforms of democracy that enable intercultural dialogue, gives voice to stakeholders and integrates systems and services through an efficient and sustainable use of the new technologies, embedded with ICT and CI capabilities. The Smart Urban Collaboration is supported as the intersection of "smart" and "sustainable" [28]. Besides, some scholars have also mentioned that it is what explains a certain enthusiasm.

E. An interdisciplinary definition of Smart Territory

The term smart territory has not yet been considerably used in the scientific literature. For instance, a research in the Scopus database using the term tag "smart territory" OR "smart territories" finds 8360 documents that contains the term and only 371 that contains it, precisely, in the title, abstract or keywords, as detailed in Table I. This table presents a search done considering three different reference international databases: SCOPUS, IEEEXplore and Web of Science (Web of Knowledge). The following keywords were considered: Smart City (SC); Sustainable Digital Transition (SDT); Smart Territory (ST); Smart Governance (SG); and Territorial Development (TD). It summarizes the number of items found in two different types of search: *considering all document; or *only metadata. For WoS database, only title was considered in the restricted search.

Hence there is still a lack of an approach of the concept from the experts on territory itself. The focus here is to promote an interdisciplinary vision and also guide developers and computer scientists when referring to the digitalization of the space and society.

The perspectives of smart territories adopted so far focus on specific and simplistic targets. For example, referring to the process of resilience building in the globalization scenario [29]. Or related to social innovations which aim a sustainable imaginary of a geographic space. As well as the smart territory as the intersection between the rural and the non-metropolitan urban areas [30].

Facing this limited conceptualization, this paper supports and proposes a new understanding of smart territory. An interdisciplinary approach evolving the concepts of sustainable territorial development, strategic spatial planning and smart governance.

- A smart territory is a bounded space (from communities to a region) with particular features due to the anthropic influence and which the digital transformation is an outcome of a participatory, rational and comprehensive planning strategy. Thus creating new values without compromising the territorial capital of the territory at issue and its adjacent.

III. Cryptocurrencies as enablers of Smart Territories

A. Distributed Ledger Technologies and applications

The Distributed Ledger Technologies (DLT) represent the broad scope of distributed databases. Such as the blockchain technology, that flourished mainly with the white paper of Satoshi Nakamoto [31], in which the Bitcoin was presented. Many enthusiasts see this technology as influential as the web in the nineties. The principal reason is due to its capacity of solving trust problems and digital transfer of values [32]. Additionally, the World Economic Forum expects that 10 per cent of the global GDP will be stored in those distributed ledgers in 2030 [33].

The major benefits are associated with the increased transparency (corruption and fraud reduction not only in the public sector, but also in the international trade and logistics), individual autonomy (there is no need of a central authority), accountability and security [2]. Diverse applications have been implemented not only in the financial technology (fintech) sector, but also in the property registry, genuine digital identities for political participation, traceability [33], among others that already exists or are in phase of being implemented [3]. Nonetheless, it is relevant to highlight that such technology is not going to solve every single problem in simplistic way.

Those DLT, by the way, are a combination of different technologies that were already in the scope of computational science and engineering for awhile. First the peer-to-peer (P2P) communication, which is intrinsically related with decentralized and distributed systems and allows an egalitarian exchange between two parties without the need of a third, thus augmenting the availability and reducing transactions costs [2]. Another elements is the timestamped transactions, each block is authenticated correlating with the previous one through cryptographic *hashs*. Thus, the cryptography is fundamental in terms of security and immutability in order to build the network record of transactions [32]. The following tool is the mechanism of consensus, basically an algorithm which assures that the data in the network be the same for all the participants involved and it is crucial for the volatility of transactions [33]. This feature of being constantly updated up to reaching consensus with timestamped transactions is what differs DLT from other conventional databases.

It has been only 4 years since the young Russian-Canadian Vitalik Buterin launched the Ethereum blockchain. By that occasion, the applications of the DLT were expanded through the possibility of implementing smart contracts, a concept introduced by Nick Szabo in 1993, smart property and Distributed Autonomous Organisations (DAO) [34]. Nowadays, these smart contracts can be understood as computational codes inside a block of data that takes decision automatically. Furthermore, given the difficulty and unlikelihood of modifying these blocks, a vast number of applications are promoted. The challenges of this mega-trend are related to privacy and governance, mainly with regards to the immutability of DLT and "the right to be forgotten" [35]. This without mentioning the enormous levels of energy required for the most used current consensus mechanisms, Proof of Work, and the potential of quantum computing in breaking modern cryptography.

On the other hand, scientists are engaged in searching for innovative solutions, such as Proof-of-Stake and Proof of Byzantine Fault Tolerance [34][36][37] and other voting

	Keywords				
Database	SC	SDC	ST	SG	TD
All Fields					
1. SCOPUS	81.740	7.683	8.360	22.899	75.360
2. IEEEXplore	48.662	6.189	3.695	4.155	3.322
3. Web of Science	7.747	82	294	862	10.307
Restricted search					
1. SCOPUS	11.508	126	371	1.046	10.268
2. IEEEXplore	8.318	13	138	245	116
3. Web of Science	2.623	1	15	105	794

TABLE I
KEYWORDS SEARCHED IN DIFFERENT DATABASES, JANUARY, 2018.

strategies, which could use negotiation protocols in order to reach P2P agreements.

B. Complementary and digital currencies

Complementary Currencies Systems (CCS), also called alternative currencies, social currencies, local or community currencies have been presented as an important strategy for development [38]. This by localizing the economy, strengthening and facilitating the exchange between parties of a given community [39] and thus promoting economic development and financial inclusion [40]. In addition, several authors have made evident the role that this mechanism will have in a short and medium term [41]. Even though a great number of local currencies have existed for centuries, the scientific research about the theme has been mainly approached since the middle eighties. The key point is that fiat money is understood as store of value and not as an community agreement of exchange, hence making difficult its circulation [41].

There are diverse examples of complementary currencies around the globe, some of them using physical coins, others the time and others virtual money. Some models of complementary currencies are the LETS (Local Exchange Trading Systems) that are local innovations non-for-profit oriented that allow members of a community to negotiate and establish their own values and services [42]. The main characteristics of the LETS are based on the mutual-credit banks, in which the member starts with a zero amount, there is no obligation of trade, there is no interest and information about the trade balance is always available for all members [39], known as rich list. Another type is the timebank, existing in a vast scale in the United States and in which, basically, the needs and resources are measured in a time scale. The quantity of time invested in the network is rewarded, in a sense that the expansion and durability of the network itself are the main objectives. Local currencies target mainly consolidate the territorial cohesion in a limited space, guaranteeing the local economic control; mobilizing and assuring the economy where it is created [42].

Technological innovations, such as the e-payment or e-money have entailed the adoption of digital instruments in complementary currencies [40]. There is a set of open source platforms to support those initiatives, such as the Community Exchange Systems (CES) and the Cyclos. Furthermore, for instance, the European Commission launched in 2015 a program called D-CENT [43] that envisioned the creation of social digital currencies for communities that were intending to increase citizens participation in local economies. The most interesting in the context of blockchains is the Social Kronas, the municipal currency of the Icelander capital Reykjavik in which the dweller is rewarded for its political engagement. By the way, this consensus mechanism was named Social Proof-of-Work [43], and covers other actions in the real world in order to promote collective values. In the South American context it is worthy to mention the MonedaPAR, an Argentinian complementary currency [44] that is being implemented using blockchain technology.

C. The Bancor Protocol as an enabler

The Bancor is a start-up based on Tel Aviv, Israel, and which its foundation (Bprotocol Foundation) is located in Zurich, Switzerland. The protocol was launched in February of 2017 in Paris. In July of 2017 happened its ICO (Initial Coin Offering) reaching a record of 153 million US dollars and beyond that, causing a critical slowdown in the Ethereum blockchain. The protocol was chosen for this paper as an example because it allows the creation of non-for-profit decentralized and automated markets [45].

According to the white paper [45], the protocol fosters as its main objective strengthening the long-tail phenomenon. This one is related to the fact that small currencies when aggregated have higher relevance when compared to the great ones. According to the founders of Bancor [45], by assuring the liquidity of currencies created by anyone (no need to be an expert developer) is the key factor for the long-tail to happen. These may entail an abundance of monetary diversity, which is fundamental to reach the equilibrium between the resilience and efficiency of monetary systems, hence promoting indeed sustainable development [42].

Some main mechanisms of this open code protocol can be listed as follows.

- The platform allows a mechanism of price discovery and liquidity for tokens through the smart contract, named smart tokens;
- Anyone involved can instantly buy and sell these smart tokens as exchange of anyone of its reserves. These solves the problem of the “double coincidence of wants”;
- The price is continuously calculated;

- There is no "spread", term that represents in traditional finance the difference between the prices of buyers and sellers along the time.

The Bancor was projected with the obligation of a reserve that can be either the Ether, from Ethereum, or any other token in the ERC20 standard. In this way, only by creating a reserve it is possible to issue smart tokens. Thus, the code written in a smart contract adjusts the price in a continuous way, always guaranteeing the reserve of the smart tokens. As long as the reserves increase new tokens are issued and sustained for a stable value. Again, there is no need of being commercialized for the smart token to become liquid and the lack of liquidity is the core problem of small currencies to thrive.

The creator of the token is who defines the value that he or she intends to keep as a constant reserve according to the required finality. Once it defined, the adjusted price can be already calculated as function of the transaction size. These called effective price makes sure that several small transactions have the same cost of a big one.

In India, several projects for poverty alleviation based on technological solutions such as Bancor or similar structure have been discussed. In Europe, diverse projects for financial crisis rescuing have also manifested the interested on this technology. In this paper, Bancor is presented as an example, in order to push similar mechanisms forward.

IV. An idea of complementary cryptocurrencies to promote smart territories

The potential of implementing a comunity currency in a blockchain is enormous. Mainly with regards to the efficiency and transparency of transactions; the scalability and the creation of various complementary currencies clusters that share not only knowledge, but value. On the other hand, it is of extreme importance to make clear the risks of this process, principally about the complexity of these systems and the need of financial, infrastructural, human and social capital in a vast scale to be implemented. The objective here is to illustrate this scenario and not to define a specific model to me adopted.

It is important to mention the distinction between complementary currencies and cryptocurrencies. While the first were presented in the subsection III-B, the latter refers mainly to blockchain-based currencies, updated with peer-to-peer communication protocols (usually, with several copies of transactions spread through the network), that are supported by the elements described in the subsection III-A. These blockchain-based ones represent only one of the category of community currencies circulating in a digital format[46]. In this paper, the term complementary cryptocurrencies is proposed to correlate the use of these technological innovations for complementary currencies systems, but it could also be called *digital community currencies*. So far, CCS has used physical or digital money (being it through card, SMS or mobile application), but emphasizing the non-for-profit profile. Furthermore, it is relevant to mention that the creator of this complementary currencies can be, for example, already existing community banks with their respective complementary currency[47].

According to Guasca [48], the DLT will certainly influence the scope of CCS in the near future. These influence will happen mainly in three levels:

- The scalability of a complementary currency: in case of complementary currency that aims to scale-up its activities from the neighborhood to the municipal or regional level, for example;
- A network of complementary currencies: each node of the network would issue its own currency that could be exchangeable with other, creating consolidated clusters in parallel of conventional money;
- The capacity of exchanging these complementary cryptocurrencies with other global cryptocurrencies: by tokenizing the CCS and allowing it to be trade in open platforms.

A. The risks and perils

The risks associated with public blockchains are mainly related to the volatility that current cryptocurrrencies face. Even it not being a technological issue, but sociotechnical and regulatory ones. Actually, these presented complementary currencies are threatened if exchangeable with others such as Bitcoin as the latter functions in opposite mechanism, even though there are a lot of commonalities in terms of decentralization, autonomy and consensus-building. Perhaps the ideal would be implementing these complementary cryptocurrencies in closed blockchains, but further research must be carried to assess the feasibility in a real case scenario.

Additionally, localized complementary currencies at the neighborhood level already functioning may be drastically jeopardized if implemented in a blockchain, being its adoption not recommend in the master's thesis of Mnica Gusca[48]. The interoperability is directly proportional to the required complexity. Furthermore, the technology plays a secondary role in these systems and must be understood as an enabler.

B. The importance of governance

The complementary currencies must be interpreted as a common good and for such the issue of governance is crucial for the life lasting of these systems. As highlighted by Aaron Wright and Primavera de Fillipi [49], distributed governance is going to shape our society in a structural way as it competes with governments, markets and enterprises. The case of Bancor, which so far it was built on the Ethereum and was used here as an example, it could use the Decentralized Autonomous Organizations to facilitate and develop decentralized and inclusive governance structures [50]. The smart urban collaboration proposed in the Section II-D must be the path to follow.

The community in partnership with territorial planners, policy makers and developers should elaborate a set of restrictions and principles to assure the command of these complementary cryptocurrencies in the local dimension. At this point, developers and engineers must take this into account and create systems and decentralized applications that facilitate this procedure. Furthermore, The DAO may play an important

role in these process since it can guarantee an automated and transparent democratic governance while fostering the perceived ease of use of this complementary cryptocurrencies.

V. Final remarks and future research

The thematic of smart cities at the same time that has been loosing its strength in the scientific literature, it has been explored even more by public and private agents. The risks and uncertainties inherent to the digitalization of the space and society are even more augmented when there is a lack of a unified approach. In this perspective, the paper aimed to promote the concept of smart territories by aggregating interdisciplinary concepts which covers issues of sustainable territorial development, strategic spatial planning and smart governance.

The reason through which this new terminology was adopted is in order to consolidate the geographical aspect in the introduction of modern technologies in the territory. By doing so, the social, cultural and political characteristics of the contexts can be transformed in plans of action supported by computational intelligence, IoT, distributed ledger technologies and others.

Based in the pragmatic feature of the strategic planning of the territory, the paper intended to assess the role of complementary currencies as a tool for local development inside the scope of distributed ledgers, blockchains and crytocurrencies. The main findings is that there is already some cases in the literature, however, as a quite state-of-the-art topic the exploratory study was conducted. Another point found out is that exists already technological tools that allows the creation of complementary currencies clusters, the scalability of these systems, as well as its exchangeability with other current cryptocurrencies. Nevertheless, future research must be done in order to check the real feasibility of its implementation, since it is only in its embryonic stage.

There is a lot of potential research to be carried, being it in the analysis of adoption, use and acceptance of these technological innovations by community banks, or in study cases, or measuring the optimal point between the resilience and efficiency of these systems. It is relevant to highlight, conversely, that identifying the key elements of the governance of complementary cryptocurrencies as being the focus. It is detrimental to guarantee the equilibrium of these technologies without compromising the real objectives of complementary currency systems in order to promote smart territories. In few words, the idea supported in this paper was basically the potential of creating clusters of already existing community currencies that my be exchangeable among each others, without geographical proximity being a constraint and therefore building a robust complementary monetary system, which is the case of Brazil and its Community Development Banks as promoters of those complementary currency systems. Nonetheless, it is also quite important to assess the changes in costs and time that these implementations may entail in a more in-depth way.

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References

[1] A. Meijer and M. P. R. Bolvar, "Governing the smart city: a review of the literature on smart urban governance," *International Review of Administrative Sciences*, vol. 82, no. 2, pp. 392–408, 2016.

[2] K. Christidis and M. Devetsikiotis, "Blockchains and smart contracts for the internet of things," *IEEE Access*, vol. 4, pp. 2292–2303, 2016.

[3] M. Walport, "Distributed ledger technology: Beyond blockchain," *UK Government Office for Science*, 2016.

[4] A. Dorri, S. S. Kanhere, and R. Jurdak, "Towards an optimized blockchain for iot," in *Proceedings of the Second International Conference on Internet-of-Things Design and Implementation*, ser. IoTDI '17. New York, NY, USA: ACM, 2017, pp. 173–178. [Online]. Available: http://doi.acm.org/10.1145/3054977.3055003

[5] A. Razo, "Strategic embeddedness and the microfoundations of collective action: A comparative institutional analysis of the rule of law and informal institutions in cooperation games," *Journal of Theoretical Politics*, vol. 28, no. 1, pp. 105–137, 2016. [Online]. Available: https://doi.org/10.1177/0951629815586879

[6] A. Pike, A. Rodríguez-Pose, and J. Tomaney, "What kind of local and regional development and for whom?" *Regional Studies*, vol. 41, no. 9, pp. 1253–1269, 2007.

[7] R. Boyer, "Sociotechnical transitions and urban planning: A case study of eco-cohousing in tompkins county, new york," *Journal of Planning Education and Research*, vol. 34, no. 4, pp. 451–464, 2014.

[8] P. Healey, "Relational complexity and the imaginative power of strategic spatial planning," *European Planning Studies*, vol. 14, no. 4, pp. 525–546, 2006. [Online]. Available: https://doi.org/10.1080/09654310500421196

[9] L. Albrechts, "Ingredients for a more radical strategic spatial planning," *Environment and Planning B: Planning and Design*, vol. 42, no. 3, pp. 510–525, 2015. [Online]. Available: https://doi.org/10.1068/b130104p

[10] ——, "Strategic (spatial) planning reexamined," *Environment and Planning B: Planning and Design*, vol. 31, no. 5, pp. 743–758, 2004.

[11] A. Rallet and A. Torre, "Geography of innovation, proximity and beyond," in *The Elgar Companion to Innovation and Knowledge Creation*, ser. Chapters. Edward Elgar Publishing, 2017, ch. 26, pp. 421–439.

[12] L. Albrechts, "Bridge the gap: From spatial planning to strategic projects," *European Planning Studies*, vol. 14, no. 10, pp. 1487–1500, 2006.

[13] S. Coleman and R. C. Sampaio, "Sustaining a democratic innovation: a study of three e-participatory budgets in belo horizonte," *Information, Communication & Society*, vol. 20, no. 5, pp. 754–769, 2017. [Online]. Available: https://doi.org/10.1080/1369118X.2016.1203971

[14] L. Albrechts, "Strategic (spatial) planning reexamined," *Environment and Planning B: Planning and design*, vol. 31, no. 5, pp. 743–758, 2004.

[15] S. Kraus, "Negotiation and cooperation in multi-agent environments," *Artificial intelligence*, vol. 94, no. 1-2, pp. 79–97, 1997.

[16] L. Jean, "Dahl (robert a.) lindblom (charles e.) - politics, economics and welfare. planning and politico-economic systems resolved into basic social processes," *Revue conomique*, vol. 6, no. 2, pp. 328–329, 1955.

[17] S. Iassinovski, A. Artiba, V. Bachelet, and F. Riane, "Integration of simulation and optimization for solving complex decision making problems," *International Journal of Production Economics*, vol. 85, no. 1, pp. 3–10, 2003.

[18] A. Z. Bafarasat, "In pursuit of productive conflict in strategic planning: project identification," *European Planning Studies*, vol. 24, no. 11, pp. 2057–2075, 2016. [Online]. Available: https://doi.org/10.1080/09654313.2016.1231800

[19] P. Healey, "The treatment of space and place in the new strategic spatial planning in europe," *International Journal of Urban and Regional Research*, vol. 28, no. 1, pp. 45–67, 2004. [Online]. Available: http://dx.doi.org/10.1111/j.0309-1317.2004.00502.x

[20] Y.-C. Chen, "Smart urban governance: An institutional and system perspective," 10 2013.

[21] J. Badach and M. Dymnicka, "Concept of good urban governance and its application in sustainable urban planning," *IOP Conference Series: Materials Science and Engineering*, vol. 245, no. 8, p. 082017, 2017. [Online]. Available: http://stacks.iop.org/1757-899X/245/i=8/a=082017

[22] R. P. Dameri and C. Benevolo, "Governing smart cities: An empirical analysis," *Social Science Computer Review*, vol. 34, no. 6, pp. 693–707, 2016.

[23] N. T. Buck and A. While, "Competitive urbanism and the limits to smart city innovation: The uk future cities initiative," *Urban Studies*, vol. 54, no. 2, pp. 501–519, 2017.

[24] P. Ballon and D. Schuurman, "Living labs: concepts, tools and cases," *info*, vol. 17, no. 4, p. null, 2015. [Online]. Available: https://doi.org/10.1108/info-04-2015-0024

[25] A. Cocchia, *Smart and Digital City: A Systematic Literature Review*. Cham: Springer International Publishing, 2014, pp. 13–43.

[26] E. G. Carayannis and D. F. J. Campbell, "Open innovation diplomacy and a 21st century fractal research, education and innovation (freie) ecosystem: building on the quadruple and quintuple helix innovation concepts and the "mode 3" knowledge production system," *Journal of the Knowledge Economy*, vol. 2, 2011. [Online]. Available: https://doi.org/10.1007/s13132-011-0058-3

[27] M. P. Rodríguez Bolívar, *Characterizing the Role of Governments in Smart Cities: A Literature Review*. Cham: Springer International Publishing, 2016, pp. 49–71.

[28] M. Deakin, "Smart cities: the state-of-the-art and governance challenge," *Triple Helix*, vol. 1, no. 1, p. 7, Nov 2014. [Online]. Available: https://doi.org/10.1186/s40604-014-0007-9

[29] M. Sargolini, *Environmental Networks for Smart Territories*. Milano: Springer Milan, 2013, pp. 69–84.

[30] G. D'Angelo, S. Ferretti, and V. Ghini, "Multi-level simulation of internet of things on smart territories," *CoRR*, vol. abs/1611.01325, 2016. [Online]. Available: http://arxiv.org/abs/1611.01325

[31] S. Nakamoto, "Bitcoin: A peer-to-peer electronic cash system, http://bitcoin.org/bitcoin.pdf," 2008.

[32] W. Al-Saqaf and N. Seidler, "Blockchain technology for social impact: opportunities and challenges ahead," *Journal of Cyber Policy*, vol. 2, no. 3, pp. 338–354, 2017. [Online]. Available: https://doi.org/10.1080/23738871.2017.1400084

[33] N. Kshetri, "Can blockchain strengthen the internet of things?" *IT Professional*, vol. 19, no. 4, pp. 68–72, 2017. [Online]. Available: doi.ieeecomputersociety.org/10.1109/MITP.2017.3051335

[34] J. Poon and V. Buterin, "Plasma: Scalable autonomous smart contracts," *White paper*, 2017. [Online]. Available: https://plasma.io/plasma.pdf

[35] A. Verheij, "The right to be forgotten a dutch perspective," *International Review of Law, Computers & Technology*, vol. 30, no. 1-2, pp. 32–41, 2016. [Online]. Available: https://doi.org/10.1080/13600869.2015.1125156

[36] M. Castro, B. Liskov *et al.*, "Practical byzantine fault tolerance," in *OSDI*, vol. 99, 1999, pp. 173–186.

[37] A. Kiayias, A. Russell, B. David, and R. Oliynykov, "Ouroboros: A provably secure proof-of-stake blockchain protocol," in *Annual International Cryptology Conference*. Springer, 2017, pp. 357–388.

[38] B. Cohen, "The rise of alternative currencies in post-capitalism," *Journal of Management Studies*, vol. 54, no. 5, pp. 739–746, 2017. [Online]. Available: http://dx.doi.org/10.1111/joms.12245

[39] M. S. Peacock, "Complementary currencies: History, theory, prospects," *Local Economy*, vol. 29, no. 6-7, pp. 708–722, 2014.

[40] J. P. de Albuquerque, E. H. Diniz, and A. K. Cernev, "Mobile payments: a scoping study of the literature and issues for future research," *Information Development*, vol. 32, no. 3, pp. 527–553, 2016. [Online]. Available: https://doi.org/10.1177/0266666914557338

[41] M. Lietaer, Bernard & Ardron, "Complementary currency innovation: Self-guarantee in peer-to-peer currencies." *Currency Solutions for a Wiser World*, 2006.

[42] B. Lietaer, "A proposal for a brazilian education complementary currency,," *International Journal for Complementary Currency Research*, vol. 10, pp. 18–23, 2006.

[43] E. Comission, "Decentralized citizens engagement technologies," 2015.

[44] "MonedaPAR argentian complementary currency in a blockchain," http://www.monedapar.com/, accessed: 2018-01-30.

[45] E. Hertzog, G. Benartzi, and G. Benartzi, "Bancor protocol: continuous liquidity for cryptographic tokens through their smart contracts," *White paper*, 2017.

[46] E. S. Diniz, Eduardo Henrique; Siqueira and van Heck, "Taxonomy for understanding digital community currencies: Digital payment platforms and virtual community feelings," *GlobDev 2016*, vol. 10, 2016. [Online]. Available: https://aisel.aisnet.org/globdev2016/10/

[47] A. K. Diniz, Eduardo Henrique; Cernev and E. Nascimento, "Mobile social money: an exploratory study of the views of managers of community banks," *Revista de Administrao - USP*, vol. 51, pp. 299–309, 2016. [Online]. Available: http://www.sciencedirect.com/science/journal/00802107

[48] M. Gusca, "Assessing the impact of blockchain on complementary currencies," Master's thesis, Erasmus Mundus Sustainable Territorial Development, University of Padua, Italy, 2017.

[49] A. Wright and P. De Filippi, "Decentralized blockchain technology and the rise of lex cryptographia," *SSRN*, Mar. 2015. [Online]. Available: https://ssrn.com/abstract=2580664

[50] U. Chohan, "The decentralized autonomous organsations and governance issues," *SSRN Electronic Journal*, 2017.

Chapter 3

SMART CITIES AND OPERATIONS RESEARCH

> "Without continual growth and progress, such words as improvement, achievement, and success have no meaning."
>
> Benjamin Franklin

The transportation ecosystem on SC is highlighted in this chapter, dealing with the identification of technology for mobility, thinking in cities' sustainability throughout the integration with Smart Grids [Bonetto et al., 2020], which involves the use of electric cars and microgrids decentralized energy generation. The study explores the potential that it brings for citizens in the scope of the wave of innovation discussed within smart cities [Coelho et al., 2019c] and how energy plays a fundamental role in the offer of modern cities' services. In addition, the studies presented here reinforces how CI allows precise cities' decision-making. In addition, the consideration of emerging concepts such as distributed ledgers and blockchain as a tool for promoting trust, lower costs on data operations, transparency and exchange of value on services used by citizens. The urban mobility is nowadays counting with CI techniques and interactive tools to assist transportation, those are used to improve services, cut operational costs and proportionate more balanced systems, being also responsible for promoting a sustainable environment for the citizens and companies, optimizing costs in short, medium and long term [Oliveira et al., 2020a]. The city evolution also contribute for the development of new tools with startups throughout public and private incentives, which reinforces that new technologies can proportionate and facilitate the city and citizens integration. In order to bring citizens closer to justice [Coelho et al., 2017b] in a more fair manner, applications inspired by operational research can idealized

some old ideas, as integrative and trustable judicial systems, which involves the design a voting protocol that use socio-demographic criteria of each individual's profile for assisting decision making of judges [Coelho et al., 2019d]. Some contributions in this Chapter, are:

- Discuss about mobility, energy, optimization of social participation in the city;
- Presents an up-to-date background of applied technologies for transportation, which a perspective of social sciences;
- Identify promising technologies to be developed for mobility and the potential that they could bring to citizens in the scope of the wave of innovation discussed within smart cities;
- Emphasize that sustainable urban environment can be responsible to change the economy.

Papers included in this chapter:

- **Oliveira, T.A.**; Gabrich, Y.B.; Ramalhinho, H.; Oliver, M.; W. Cohen, M.; S. Ochi, L.; Gueye, S.; Protti, F.; A. Pinto, A.; V. M. Ferreira, D.; M. Coelho, I.; N. Coelho, V. Mobility, Citizens, Innovation and Technology in Digital and Smart Cities. Multidisciplinary Digital Publishing Institute. Future Internet 2020, 12, 22. [Oliveira et al., 2020a];
- Coelho, V. N., **Oliveira, T. A.**, Figueiredo, Iara V. O., Souza, Marcone J. F., Veloso, Iuri. A multi-criteria view about judicial and legislative decision making in digital cities and societies. Urban Computing. 1ed.: Springer International Publishing, 2019, v. 1, p. 209–220, doi: 10.1007/978-3-030-12255-3_13. [Coelho et al., 2019d]
- Coelho, V. N., Gabrich, Y. B., **Oliveira, T. A.**, Ochi, L. S., Barbosa, A. C., & Coelho, I. M. (2019). When CI and Decentralized Systems Effectively Meet Smart Cities and Grids. Urban Computing. 1ed.: Springer International Publishing, 2019, v. 1, p. 239-249, doi: 10.1007/978-3-030-12255-3_15. [Coelho et al., 2019c];

Appendix A.1:

- Coelho, V. N., Veloso, I. F., **Oliveira, T. A.**, & Veloso, I. (2017). A multi-criteria view about judicial and legislative decision making in digital cities and societies (In Portuguese). In Proceedings of the XLIX Brazilian Symposium of Operational Research (SBPO), September 16–19, Blumenau, Brazil. [Coelho et al., 2017b].

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Article

Mobility, Citizens, Innovation and Technology in Digital and Smart Cities

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Abstract: Cities are constantly transforming and, consequently, attracting efforts from researchers and opportunities to the industry. New transportation systems are being built in order to meet sustainability and efficiency criteria, as well as being adapted to the current possibilities. Moreover, citizens are becoming aware about the power and possibilities provided by the current generation of autonomous devices. In this sense, this paper presents and discusses state-of-the-art transportation technologies and systems, highlighting the advances that the concepts of Internet of Things and Value are providing. Decentralized technologies, such as blockchain, are been extensively investigated by the industry, however, its widespread adoption in cities is still desirable. Aligned with operations research opportunities, this paper identifies different points in which cities' services could move to. This also study comments about different combinatorial optimization problems that might be useful and important for an efficient evolution of our cities. By considering different perspectives, didactic examples are presented with a main focus on motivating decision makers to balance citizens, investors and industry goals and wishes.

Keywords: smart cities; digital cities; blockchain; citizens; sustainable development; IoT; internet-of-value; information and communication technologies; mobility

Key Contribution: Highlights the importance of technology for mobility and the potential it brings for citizens in the scope of the wave of innovation discussed within smart cities. This study reinforces how computational intelligence allows precise cities' decision-making. Blockchain as a tool for promoting trust, lower costs, transparency and exchange of value on services used by citizens.

1. Introduction

Aligned with machines' advancement and the new generation of personal devices, cities are evolving into a new paradigm called Smart Cities (SC) [1]. This evolution, closely related to equipment embedded with techniques from the field of Computational Intelligence (CI), is occurring in urban and rural areas. In addition to promoting decentralization of the current system, these new cities' paradigms open doors for different autonomous agents, devices with CI capabilities, to optimize and manage their own interests. A complex decision-making scenario has been emerging based on historical data and an increasing potential of solving mathematical problems. While each of these software-based systems optimizes specific goals, simulations with multi-agent scenarios [2,3] should focus on improving overall performance. While this combination of technologies emerges, there is a huge trend moving to decentralized solutions, such as those based on Distributed Ledger Technologies (DLTs). The hidden layer behind the intelligence of these selfish agents and decentralized entities is the core of the future Smart and Digital Cities [4], which will be presented along this paper.

The expected outcomes of current transformations encompass systems that should reach favorable agreements, considering citizen opinions and participation of all involved entities. However, coordinating these agents handling a big volume of historical and real-time information [5] usually leads to the resolution of combinatorial optimization problems [6,7], which are undoubtedly a challenge for modern societies and technological development. In this sense, a multi-criteria view of this transition [8], aligned with the management of these emerging decentralized cities [9], should be carefully considered to address different stakeholders' perspectives.

It is noteworthy that connecting the dots between what the academy and industry have been doing, and how to take profit from this previous knowledge, may save time and create pillars for future implementations. Since investments and the boom of novel devices are usually sponsored by the private sector, which is usually profit-driven, we emphasize the importance of taking into account all involved partners wishes, which would contribute to a progressive and holistic development [10–12].

Blockchain based technologies are used not only for enhancing trust between parties, but also because it has the potential to reduce costs [13]. In this sense, a match between an emerging technology and private interests is evident. In particular, cities' mobility [14] and the future of the transportation systems are often one of the main concerns when talking about SC [15]. Zhuadar et al. [16] emphasized a next wave of SC intelligent systems, in which humans' ability to connect with machines is advocated. This ability mentions the possibilities of implementing operational systems that connect citizens to smart equipment, mostly embedded with Internet of Things (IoT) capabilities [17]. Nowadays, we can add this IoT design with the concepts of Internet of Value (IoV) [18,19], which combines the potential of IoT with value transfer, mostly assisted by smart contracts designed with decentralized and semi-decentralized technologies such as blockchain [20].

In summary, the main points that will be highlighted along this paper are:

(i) technological solutions that will be used in the digital cities transportation environment, both for the public and private interest;
(ii) blockchain based technologies for promoting distributed trust on transportation systems;
(iii) consider social aspects, highlighting how citizens are now interacting with the transportation services offered within the cities, such as carpooling, smart parking, and alternative transports.
(iv) discussions about the possibilities that CI inspired tools have been offering for the future of our cities, pondering a trade-off between technology and quality of life.

Ultimately, this overview paper expects to contribute with readers to:

(i) understanding some of the current transportation systems that are reality in some parts of the globe, as well as envisioning possibilities and technologies that might come to;

(ii) creating awareness among citizens, researchers, teachers and students about the importance of the transformations that are occurring in urban environments, aligned with the SC paradigms;
(iii) introducing state-of-the-art concepts about decentralized solutions, such as those using blockchain;
(iv) highlighting the importance of considering multi-objective optimization problems and multi-criteria analysis;
(v) motivating the academy and the industry to develop and work towards "fully" distributed and "transparent" approaches, in order to balance the goals of different autonomous agents;
(vi) understanding the potential that DLT technologies have in removing the trust barriers in Peer-to-Peer (P2P) Transportation systems.

In order to achieve the desired impacts, the remainder of this paper is organized simply. First, it discusses some current real applications and undergoing studies on operational research and high-performance computing in Section 2. Trends for transportation systems are pointed out inside the scope of Section 3. Finally, final considerations and future research directions are presented in Section 4.

2. The Search for an Optimized Urban Transportation Ecosystem

As mentioned by Derrible and Kennedy [21], urban transportation planning and network design is a problem that has been faced by society from the street patterns of the Roman Empire [22] to the current computational intelligence systems of our present days [23]. Logistics and urban planning problems encompass crucial aspects that can guide efficient cities' functioning and citizens life quality, such as modeling and designing in order to increase pedestrian mobility [24]. In this section, we are going to highlight advances that the optimization has been bringing for an efficient use of the transportation systems.

2.1. Graph Modeling

The topological/geometric nature of transportation systems and their dynamics motivates studies focused on graph theoretical models. Derrible and Kennedy [21] revise that graph theory dates back to 1741, when mathematician Leonhard Euler had some insights about the "The Seven Bridges of Königsberg", a problem that can be succinctly described as follows: find, if possible, a tour that traverses every edge of the graph exactly once and returns to the starting point.

Modeling the novel class of transportation problems in a efficient manner, mostly dealing with huge amounts of information, increases the chance to achieve more efficient solutions, in accordance to what decision makers are looking for. For this purpose, we highlight the use of graph clustering techniques, as in [25,26], since such tools can connect these new problems with works already addressed in the literature. For example, in [25], the problem of grouping parts to be produced and the machines that will process such parts into homogeneous cells is studied so that the number of faults (part-machine pairs that do not have relation) is minimized. The motivation for such a study comes from industrial planning and development, where optimizing transportation of parts between industrial parks is highly desired. In [26], efficient algorithms to solve the cluster editing problem (that consists of adding and/or removing the minimum number of edges in order to transform the input graph into a disjoint union of complete graphs or "clusters") have been described by the authors, motivated by applications that demand grouping data with high degree of similarity, while discarding spurious information. Such "clustered solutions" can be viewed as an attempt to cover large urban agglomerations by homogeneous, self-governing small cells that can work autonomously. A scatter search was designed by Chebbi and Nouri [27] to solve a graph with stations and nodes, for moving jointly persons and goods in urban areas, in order to minimize energy consumption within the context of smart cities.

Multi-modal transportation systems [28] are interesting examples for highlighting the actual complexity of urban transportation. This family of problems also can cover the locomotion for motor profile (reduced mobility). This kind of optimization can be dealt within the scope multi-objective

optimization [29,30]. As an example, the Minimum Coloring Cut Problem (MCCP) is defined as follows: given a connected graph G with colored edges, find an edge cut E' of G (a minimal set of edges whose removal renders the graph disconnected) such that the number of colors used by the edges in E' is minimum. A potential application of the MCCP is in transportation planning systems, where nodes represent locations served by bus and edge colors represent bus companies. In this case, a solution of the MCCP gives the minimum number of companies that must stop working in order to create pairs of locations not reachable by bus from one another. Such application is more suitably modeled by allowing a multigraph as the input of the MCCP, since two locations can be connected by bus services offered by more than a single company.

Furthermore, the so-called interruption graphs can be considered in post-disaster logistics, a problem of great importance for different events that may occur in urban centers. These approaches are suitable to assist with the human decision-making process, in particular, when huge disasters happen, such as the 2017 Irma hurricane. In order to promote better integration with citizens, it is also suggested to study and develop new techniques for processing huge graphs, using high-performance computing, in order to verify interaction between citizens, cities and social networks.

2.2. Smart Routing Problems: Multi-Objective Optimization

Vehicle Routing Problems (VRP) [31] cover a wide variety of problems faced by modern society, both in the industry and public sector. From a simple route apparently taken by a postman [32] in order to deliver packages to a set of customers, humans have been facing complex decision-making scenarios in which computers' assistance has been shown to be crucial. These challenges are now being solved without users realizing how it indeed happens. In this sense, we pinpoint the open opportunities for innovative applications that should carefully consider the users' profiles, wishes and desired goals. Furthermore, due to the current advances of many-objective visualization tools [33,34], we expect that data visualization on complex problems will start to turn into common tools used by the industry and decision makers.

Recently, an optimal trip system was claimed by Dotoli et al. [35]. At this point, we highlight the discussion about what is actually an optimal trip in the context of a multicultural SC? While some will surely enjoy specific paths (with particular amount of light, temperature, wind, etc.), others will opt for the fastest or the less noisy. In addition, the specific types of vehicles and mobility systems that each person uses is another point to be added to this multi-objective scenario [36,37]. Furthermore, when public transportation systems are considered, cost and speed is another trade-off handled when citizens use transport integration [38]. The resolution of problems in the scope of green logistics is under discussion not only by the academia [39–42] but also by the industry [43,44], which basically involve different models for calculating the cost of the routes, involving other components in the objective function equation, such as carbon emissions [45,46]. Discussions under the scope of autonomous also involve batteries and fuel cell based equipment [47]. In this sense, there is a trend in researching more sustainable transports connected with the achievement of higher profits [48], which are concepts that should match for the achievement of a widespread adoption by the industry.

Let us consider an undirected graph $G = (V, E)$, where $V = \{v_1, v_2, \cdots, v_n\}$ and $E = \{(i, j) \mid v_i, v_j \in V, i < j\}$ represent, respectively, the vertices and edges of a given graph G. Da Silva and Ochi [49] designed an Adaptive Local Search Procedure for tackling a travelling salesman problems in which the rented car could be returned or not at the nodes from a graph G. In this sense, the graph could contain dynamic points in which the users might spontaneously decide where to deliver the vehicle regarding a set of stochastic aspects. It is noteworthy that this problem can be adapted for dealing with several rented cars and car sharing systems on urban scenarios. Doppstadt et al. [50] considered routes that could be optimized according to different operating modes, such as: pure combustion mode, pure electric mode, charging mode (in which the battery is charged while driving with the combustion engine) and a boost mode (in which combustion and electric engines are combined for the drive). However, other points are still open to be considered, such as modes in which the vehicle would

charge from: breaks, solar radiation or even rapid winds streams. The study of Quercia et al. [23] also provides an idea on how routing can be considered under many different points of view, defining routes in terms of "smellwalks", in a study where participants followed different smellscapes and asked to record their experiences.

2.3. The Role of Metaheuristic and High-Performance Optimization

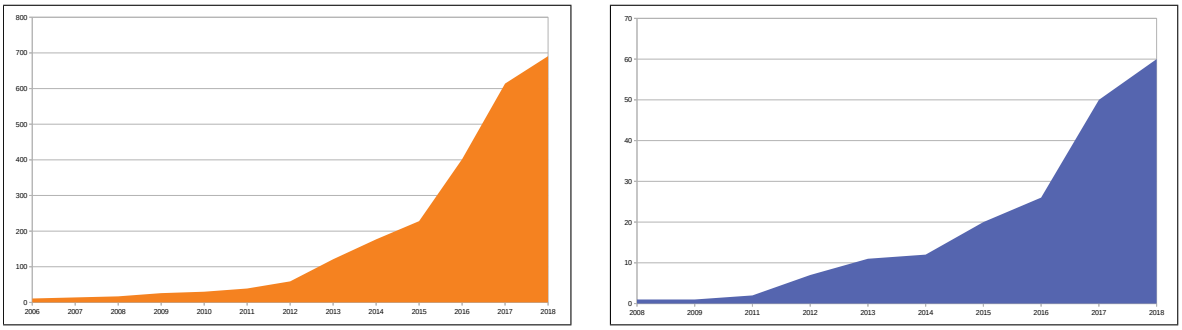
Metaheuristics are a family of methods that dates back the 1950s with the advent of Alan Turing publishing a study called "Obvious connection between machine learning and evolution", focused on an effort to find solutions to problems inspired by behaviors presented in the nature. In addition, Design by Natural Selection [51], written by Dunham et al. in 1963, presents some descriptions about a method that deals with exploration–exploitation concepts [52].

While some combinatorial problems can be solved with exact algorithms [53], NP-hard problems have a exponential nature in which the size of the problem strongly affects the time in which optimal solutions can be obtained. Added to this, the sea of big-data that is currently available in modern cities makes the decision-making scenario [54] a big trade-off between using computational resources and providing a solution as quick as possible. For this reason, this current paper emphasizes and motivates the use of metaheuristic inspired techniques [55]. One of the core of several trajectory search based Metaheuristics is the use of Neighborhood Structures [56] and, consequently, local search mechanisms [57], which have the potential of proving optimality in some specific cases. For this purpose, efficient high-performance techniques have been suggested for tackling this problems, such as Graphics Processing Units [58,59].

3. Cities Transportation Trends

This section has the goal of highlighting trends based on academic and industrial perspectives. For this purpose, in order to analyze the trends about cities' transportation, a bibliometrics search on Scopus Database was carried out.

As can be noticed in Figure 1a, the number of publications mentioning transportation systems and SC have been increasing over the last few years. Figure 1b also shows an increasing number of published papers related to the terms SC and Vehicle Routing.



(**a**) searched terms: "Smart Cities" and "Transportation".

(**b**) searched terms: "Smart Cities" and "Vehicle Routing".

Figure 1. Raw number of published documents (information extracted from Scopus on 20 June 2019).

However, in terms of the absolute values reported in graphs depicted in Figure 1, one can make conclusions about the potential that these guidelines still have for the next decade. Some of the novel transportation systems are already becoming reality, and others are still being designed. Furthermore, since 2005, more than 12,000 patents (considering a search done with the terms "Smart Cities" and "Transportation" on Scopus database) have been found, which highlight the efforts made by the industry and the academia in order to find alternative technologies for more profitable and efficient transportation solutions.

In addition, it was possible to analyze that these two keywords are addressed mainly in the fields of Computer Science, Engineering and Social Sciences, following from areas such as: Mathematics, Decision Sciences, Energy, among others. The interest in these terms among different research areas is depicted in Figure 2. Taking a brief look at the history, it can be noticed that smart cities studies started with a technological perspective, and now it is being spread among other research areas, with a significant percentage of publication in the field of social science [60].

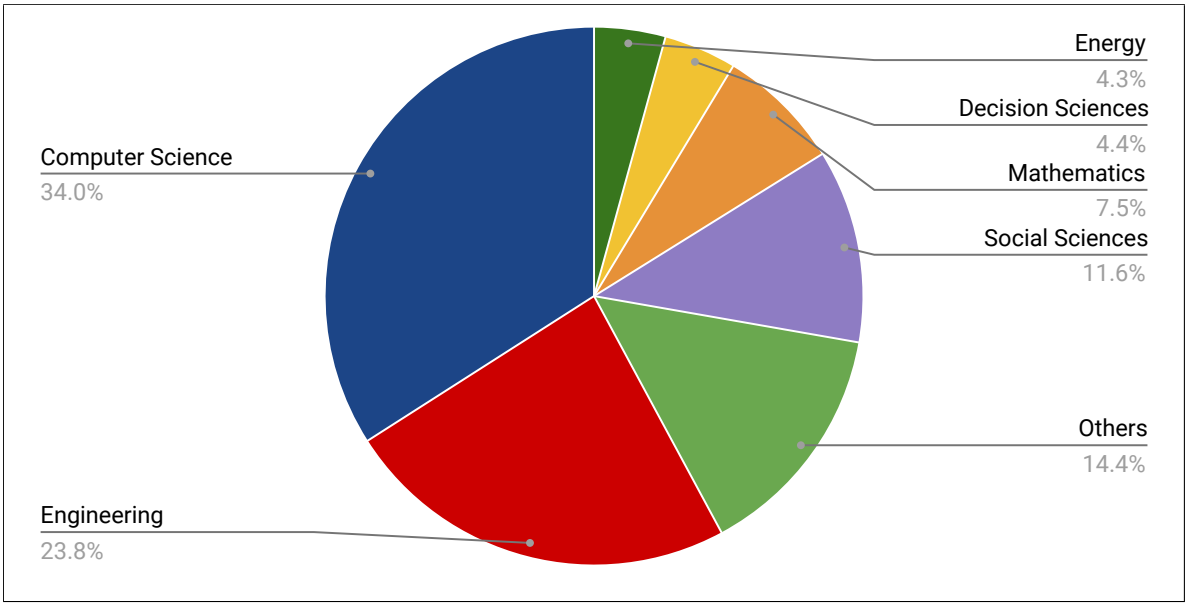


Figure 2. The rise of the interest in SCs' transportation systems by different field of knowledge (search was done on June 20th, 2019 on the Scopus database).

3.1. Mobility and Citizens

A technology becomes part of society when those who use it do not realize its presence, such as concepts surrounding ubiquitous computing [61]. Some authors discussed the growing possibilities of pervasive Artificial Intelligence [62] in SC [63]. A similar idea applies to rules/laws/policies; for example, smoking inside closed places is no longer an issue noticed or missed. For instance, Figure 3 shows a driverless bus running in the technology center in *La Défense*, Paris. In the future, citizens may not even notice the amount of technology embedded into cities' transports. Thus, technology can even be part of the cities without a daily perception about it.

(**a**) Citizens experiencing an autonomous bus.

(**b**) Apart of being driverless, several of these new technologies are being designed with purely electric system.

Figure 3. A driverless bus in *La Défense*, Paris (© Thays A. Oliveira, CC BY-SA 4.0).

If one considers the current possibilities that the decentralized transportation systems are promoting, we may notice an omnipresent interaction with citizens' interests. As an example, the actual route that a private car can take (like when you call an Uber) can be chosen according to clients' desire. This example reinforces the ability that Information and Communication Technologies (ICT) has with end-users, providing the option of choosing the most suitable transportation system that fits personal beliefs [64]. Interacting with citizens in order to guide their way of moving around is becoming a reality for those which are living in modern urban cities [65,66]. The constant interaction by means of online services proportionate the opportunity of picking different routes for reaching a destination considering real-time measured data. In this sense, different maps' services provide possible routes that use different types of transportation and forecast the arrival in the final destination within an expected time limit, considering stochastic information about traffic. Improving the interaction between citizens and public/private transportation systems represents a challenging issue. The main core of this problem relates to the design of systems that interact in a transparent, fast and reliable platform. Blockchain based technologies can be used for promoting transparency [67] and also reducing costs [68] (as will be emphasized in Section 3.5), while the other aspects related to data sharing may come consequently from other advocated points of the SC concepts.

On the other hand, we highlight the importance that urban policies have in order to regulate old transportation systems, such as noisy vehicles and pollutants' emissions, even considering the fact that electric based transportation systems are not more sustainable than fuel based ones since the problem turns to where energy is really being produced. Inside cities, it is quite obvious that less pollution will be emitted by those electric systems; thus, it is a consensus that urban environments will become more pleasurable. Regarding this aforementioned reasoning about where energy is really produced, it is noteworthy that Smart grids [69,70], in particular, microgrid systems [71], will play the role of decentralizing energy production. In addition, citizens are another key point that will become part of these smart systems, since energy consumers are also becoming suppliers [72–74].

Bike sharing comes to cover some of the cities' public transportation failures and has become a common means of transport in urban centers [75]. An efficient shared bicycle system includes stations in areas of greater demand, pondering a trade-off between cost and benefits of each station. A combinatorial optimization problem of placing such stations along the cities is crucial [76], being advocated as a crucial tool for helping urban managers. Other optimization problems were dealt in order to determine the optimal number of bikes in each station [77], most of them handling stochastic variables and modeling. Other works in the literature dealt with the simulation of such scenarios [78].

Alternative electric based transportation systems such as powered two-wheelers [79], e-scooters [80] and e-bikes [81] are now constantly being used inside urban scenarios due to their advantages when parking and great autonomy up to 40–60 km per charge, providing access to a new class of users [82,83]. This equipment is also being used for deliveries, highlighting the fact that combustion vehicles can be replaced by electric based transportation systems [84].

Real-time solutions for managing bike sharing systems have also been investigated and proposed. For dealing with such scenarios, distinct methodologies can be applied for finding empty stations, such as: the use of soft sensors, the use of apps, as well as the use of drones. An innovative and didactic video has been edited by some of the authors of this current study and has been made available (Link to a didactic video about a bike sharing system, with different modern components (drones, renewable energy, online apps and sensors), in a Smart City, produced by some of the authors of this current study: https://youtu.be/KX7SndbHOe0).

3.2. Smart Parking

Parks have played an important role in urban areas since they "allow" the access to other facilities. In urban congested cities, anybody can observe that parking his/her car somewhere may be as difficult as moving in the traffic jam because of the lack of parking places. The amount of time to find a place to park, known in the literature as the cruising time, can be huge. Like a domino effect, random cars riding in circles across the city hoping to get a parking place within walking distance and ease of parking (as well as previously parked locations) continue to contribute to inefficient time/energy spending, to congestion and to air pollution. For this and other facts, several initiatives are aimed at reducing the number of vehicles in urban centers, so-called carless cities.

Recently, studies and cities policies have been analyzing impacts of several different strategies to reconcile parking and mobility, such as a reservation system for on-street parking [85]. IoT cloud-based intelligent car parking system was introduced by Ji et al. [86]. In an attempt to develop a required system within a university campus, Ganchev et al. [87] introduced a strategy using an info station based on decentralized autonomous agents sharing the data. Collective or specialized transportation is gaining momentum, as we highlighted in Section 3.1. At the same time, hybrid/electric vehicles can be idle for a fraction of the time. During these moments, smart parking arises [88] as a set of tools that can be connected with microgrid concepts, allowing vehicle batteries to interact with the power grid [89]. This represents a positive effect of such use, whereas a growing discussion has been pointing out these novel emerging vehicles systems as unsustainable due to their energy supply impacts [90,91].

SC policies have also been discussing how to regulate and control noisy vehicles, for example, with surveillance systems [92]. The number of entities that are communicating in these new SC environments is impressive, which is another factor that motivates the study of distributed approaches, such as multi-agent systems [93]. Other alternative transportation systems, such as the use of traditional and electrical bicycles, scooters, hoverboards and skateboards, involve different parking logistic problems that must be solved by managers of a city or companies that operate in the sector.

In an operational point of view, CI tools should try to find solutions that handle the following questions:

(i) Where is the parking located that makes it easier access to activities [87]? What size should they have? What are the transportation systems that this parking will cover?
(ii) How should these new operators (parking assistants) organize their routes to satisfy all demands at minimum costs?
(iii) How can the price be evaluated to charge customers for this service?
(iv) Is it better to have a flexible organization in which pickup and delivery of the cars may be done at any point, or a more rigid one where the pickup and delivery points are fixed stations similar to taxi ones (with the difference that, in this new station, cars will be picked instead of people)? Where can those parking assistant stations be located?

(v) What is the system centered on? Citizens (target age, common local activities) or cost (greening techs and time savings)?

Questions (i) and (ii) have their resolutions linked with facility location problems, including a non-standard variant of the TSP, which can be solved using exact methods or metaheuristics (as pointed out in Section 2.3). The question (iv) falls into the class of VRP (pickup and delivery) with the additional constraints between a pickup and a delivery point, associated with a demand, an agent should park the customer car somewhere. The pricing problems (question (iii)) can make the service attractive or not, as well as considering forecasting mechanisms that act in the market with information of energy consumption, generation and price [94].

However, even considering the power of actual algorithms, no new organizational and CI system can be validated and implemented using only optimization techniques because many aspects are not considered, or, if included, they would lead to higher technical difficulties. For instance, we can highlight the following points to be considered: uncertainty on the congestion phenomenon; uncertainty on the customer plans (list of activities to perform); uncertainties on traveling times; and the effect of multiple similar demands on the traffic congestion.

Consequently, studies on multi-agent simulation (as we introduced in Section 3.4) are now a standard technique [95] used to understand what may happen if a new organization intervenes in a city life (including traffic, and environmental impacts). Taking into account that an urban area is a complex system, counter-intuitive consequences may occur which cannot be viewed simply by solving some optimization problems. Reference [94] also dealt with a parking selection problem in an SC scenario, their work uses a multi-agent flexible negotiation mechanism to address the parking space by taking into account the car owner preferences in locations, parking vendors' preferences regarding car park occupancy and social city benefits.

The insertion of renewables is also in connection with electric powered transportation systems, in which new challenges arise. On the other hand, electric based vehicles require a different moving paradigm, in which they should be smartly charged. In this sense, power dispatching systems [96] are incorporating Vehicle-to-Grid (V2G) in their daily schedules [97], creating a new wave of parking systems with electrical capabilities. There have been efforts of studies that tried to forecast and determine the optimal time for charging these vehicles [89,98]. In addition, multi-objective models are also being developed for pondering the different cost-emissions that V2G technologies may be able to reduce and balance [99]. The reduction of waiting times in the queues of fast charging stations has also been proposed using MAS, serving as the control strategy of the network [100,101].

3.3. Electric Based Transportation Systems

The insertion of electric and hybrid vehicles has been driving advances towards the use of renewable resources, and vice versa. One can say that, in view of the massive integration of Distributed Energy Resources (DER) with microgrids [93], green transportation systems [102,103] are boosting researchers to re-analyze solutions of classical optimization problems. Although the literature have been addressing some SC troublesome logistics, the integration of renewable resources has received little attention when dealt with in connection to urban planning problems. For example, when considering the relief of a city, vehicles can optimize their routes in the search of maximum energy efficiency [50]. However, several solutions focus only on classical obstacles, disregarding the current social context and the technological evolution that we have gone through. In view of these points, a new class of problems and possibilities set up new paradigms and challenges that demand more innovative solutions.

Moreover, the immense range of alternative electric transports that is emerging (skateboards, scooters, bicycles, monowheel systems and so forth) weighs in on considering possible logistics problem, beyond hybrid or pure Plug-in Electric Vehicle have [104,105]. Nonetheless, emerging technologies should be connected in our transportation system, such as roads with solar panels that might charge and assist this structure [66,106]. At this point, we highlight the open opportunities for

managing vehicles in SC. Which point will the stakeholders balance in order to manage this system? Will it be guided by the amount of CO_2 emissions balanced with traffic jam issues? Will the acoustic pollution affect the decision-making process? Undoubtedly, multi-objective optimization problems arise when this class of problems are being dealt with.

3.3.1. Unmanned Aerial Vehicle and Emerging Technologies

The use of Unmanned Aerial Vehicle (UAV) [107], also known as Drones, or Unmanned Aircraft Systems, as transportation is reality in different sectors, from the pioneers' military applications to daily goods transportation [108]. The affordability to low-cost sensors, such as those presented in our modern smartphones, has been motivating society towards innovative flying equipment.

A study held in Beijing [109] suggested an oriented information application for assisting drones with locating charging stations. Other works in the literature also study the use of different fuel options in Smart Cities operations [110]. Indeed, this kind of emerging application would be useful in the context of drones. While the electric grid, in particular mini/microgrid systems [98], may also use these news vehicles as storage units, they are also motivating their insertion into the core of the cities since the new economic scenario may be profitable for those that want to use their batteries during idle times. Recently, the work of Coelho et al. [108] considered the use of UAVs as transportation units, defining their routes in a multi-objective manner, taking into account charging points, batteries autonomy and different aspects that might be reality in a few years. Different patents are being registered related to the use of drones for transportation. The charging of e-vehicles needs to consider energy availability along their routes, which could also be assisted by UAVs on idle times.

3.3.2. Superconducting Based Technologies

Certainly, one of the most promising technologies of this century is the advent of superconducting materials [111–113]. These have unique physical properties that will propel human beings to understand and produce technologies with lower levels of interference and noise in their vicinity. Among them, a Superconducting Quantum Interference Device (SQUID) [114] allows measurement of very small magnetic fields, with magnitude detection on the order of $10^{-15}T$. These sensors also have high sensitivity in relation to the amplification of electrical or light signals. Conventional electronics, which use semiconductor and ferromagnetic materials, have already reached a satisfactory sophistication so far. However, certain problems can only be solved with the advent of superconductors, by using Josephson junctions in components such as SQUID. This extremely sensitive sensor allows the magnetic flux to be transduced into measurable electrical signals. This device is so sensitive that it can capture the magnetic field of human hearts and brains with great precision, perhaps this explains the great rise of superconductors in medical areas. When it comes to small-scale applications, superconductors are being used in biomedicine, metrology, geophysics, digital processing, devices and sensors [115–117]. As far as superconducting sensors are concerned, superconductors are already being used in various areas of human knowledge, from physicians, astronomers, to the military [118–120]. A widely publicized application of SQUID is magnetoencephalography, a technique that allows for mapping the magnetic fields generated by the brain activities through sensors that work in conjunction with SQUIDs.

By promoting greater robustness in quantum technologies, superconductors will bring a real scientific revolution in different areas, such as emerging transportation systems [121]. The latter face challenges that will be circumvented, such as fuel economy, environmental issues, overcoming the increased demand, among others. With the advent of superconductors applied for this area, different sectors related to transportation may see its benefits [122], such as high-speed trains; boat propulsion systems; and high-powered aircraft engines.

Although significant applications in electronic devices are still difficult because of the need for operation at low temperature, superconducting materials are already under development in very high integration circuits [123]. By reducing the dimensions of the components' thermal dissipation

is limited, requiring it to be cooled by liquid nitrogen or even liquid helium. In relation to efficient superconducting electric motors, they have been inserted into some specific transports, giving rise to a new generation of turbines, coils and, consequently, electric transport, airplanes, trains, cars and ships [124–127]. An example of transport in which the superconductors are employed refers to the Maglev train [128,129]; this levitates on the rails counting, basically, only with the resistance of the air-like force of friction. Thus, Maglev trains are faster than conventional trains because they float about ten inches above the rails on a "magnetic mattress" for a lower cost and greater safety than a conventional train. These are listed as one of the best means of transport for futuristic cities [130], and can reach speeds of the order of 600 km/h, mainly due to the elimination of conventional wheels, making the friction no longer a huge barrier. Of course, this technology will also receive attention with the recent advent of SC [131,132], which has been promoting researchers to idealize insights about possible future projects [133].

With regard to storage, there is still no efficient method for large volumes of electricity. The Superconductive Magnetic Energy Storage (SMES) [134] is a promising technology that has been applied in different transportation systems [135]. The main feature that motivates SMES use, apart from its apparently linear behavior regarding energy loss, is its quick response, enabling a huge possibility for quick charging on cities' parking stations [135,136]. This system stores energy by a continuous flow in a superconducting coil. The stored relies on this superconducting coil that is basically a cryogenic with temperature below the critical superconducting temperature. A transportation system that relies on these batteries can quickly charge on sporadic stops, such as electric buses. Enterprises are already investing in this kind of technology [137,138], which will surely boost other real-world applications.

3.4. Decentralization via Multi Agent Systems

Multi Agent Systems (MAS) is a network of software agents that interact to solve problems that are beyond the individual capacities or knowledge of each agent, with either diverging information or diverging interests. MAS are quickly becoming reality given to the recent possibility of acquiring data from the various IoT based devices available in the market. In this sense, autonomous IoT agents facilitate common use of local controls, real-time tuning of control parameters, peer-to-peer negotiation protocols, automatic arming and disarming of control actions in real time, reacting and acting based on a variety of big-data. All that information is measured, processed, optionally shared, mined, forecasted, and used for guiding decision-making [139,140]. A conceptual model via MAS and IoT is usually applied through the following principles: inseparability, virtualization, decentralization, real-time capability, service orientation and modality [141,142].

Progress in mobile and ubiquitous computing is promoting work sharing between a large number of agents in an orchestrated and self-organized manner [143,144]. Regulators can act autonomously in this environment, interacting with any device in the system. For this purpose, generalist platforms should communicate in a standardized and trustful manner, providing certificates and proof-checking. All of the trust can surely be handled by using blockchain concepts (as emphasized in Section 3.5). A generic conceptual model for smart cities was illustrated in [95], highlighting how MAS and ICT can result in new generation businesses and interactions. Chen [145] proposes to delegate ambient devices through various machine-to-machine (M2M) communications. Marsa-Maestre et al. [146] developed a hierarchical arrangement of mobile agents able to personalize users' needs. As should be noticed, with proper modifications, any task can be dealt in distributed manner [145], providing benefits such as improved scalability and trust.

An initial attempt to develop a car parking locator service, within a university campus, was done by Ganchev et al. [87], considering an info station based on MAS. In a subsequent work [94], an MAS flexible negotiation mechanism was developed, taking into account car owner parking vendors' preferences and social city benefits. In recent studies, developing adaptive traffic signal control [147] was done by reinforcement learning agents. Each intersection can be controlled by a single independent agent which determines the light switching sequence. Prendinger et al. [148]

developed the Tokyo virtual living laboratory traffic simulator based on autonomous vehicle agents' interaction. Understanding road user interactions, using game theory concepts, was discussed for a scenario in Norway [149], composed of vehicles and pedestrians. Furthermore, an MAS based traffic simulation system [150] can assist autonomous vehicles in connection with VRP on dynamic scenarios fulfilled with uncertainties, in which high-performance techniques are also embedded for assisting the decision-making process. Machine learning algorithms are being extensively applied for traffic control [151] and using MAS is inevitable for reaching such complex agreements [152]. Reference [153] modeled a game theory application discussing car pooling profits and incentive expenses. The role autonomous devices with GPS capabilities can be used for achieving a more efficient and safe urban traffic [154–157]. An adaptive traffic signal control done with reinforcement learning agents was proposed in [147], in which each intersection is controlled by a single independent agent which determines the light switching sequence. It is noteworthy that each of these autonomous devices can solve different logistics problems for assisting their decision-making, in which the core of the problem solver can be in the cloud, on device, in a central or in a distributed manner.

The book "Justice: What's the Right Thing to Do?", of Sandel [158], mentions a multi-criteria scenario in which authorities decided to increase speed limit, even considering that more deaths would occur. This trade-off is undoubtedly an important point to be agreed on by the selfish agents that are crossing an intersection. A similar initiative is highlighted at a Brazilian online platform that compares maximum speed limits and traffic behavior (available online at https://www.hacklab.com.br/simulador-de-transito/).

3.5. Blockchain for Managing Cities' Transportation Data and Contracts

Besides providing an introduction about the core concepts and ideas, the authors connect Blockchain and P2P transportation systems within the scope of digital cities, as well as present a draft of an innovative Smart Contract that could manage some components of a decentralized service for transportation.

3.5.1. The Core of the Blockchain and Smart Contracts

The Blockchain technology has been gaining attention since the appearance of Bitcoin cryptocurrency [159]. Despite hype applications on the financial sector, other vertical markets have been trying to integrate its features for different assets' management. To satisfy different business needs, several Blockchain platforms have emerged concomitantly with solutions presented by other distributed ledgers' technologies (DLTs) [160–163].

At a glance, the blockchain is a distributed network with enhanced security attributes, in which the P2P architecture and cryptographic keys compose a protocol that keeps the network reliable through automatic verification processes. One of its distinguishing characteristics is how the protocol reflects the way the network behaves when a new operation is requested. For this end, the consensus algorithm is responsible for managing who should append new values on the distributed database (ledger) and the possible conflicts that might arise. Another feature is that any interaction with the platform is designated as a transaction and is recorded on a new blockchain state.

Smart contracts are algorithms designed for being interpreted by specialized virtual machines, throughout its conversion to opcodes. Those virtual machines, usually, specifically designed for each blockchain project, often call precompiled scripts that optimize the calculus of commonly used functions. After being registered throughout a transaction, they are identified by a unique hash. In fact, in Bitcoin, NEO Blockchain and several other blockchain projects, the standard addresses that we often see are all smart contracts with a simple functionality of pushing a set of bytes and calling an opcode often known as a witness checker. This allows the creation of distributed applications (DApps) to serve different business demands [164,165].

However, Blockchain follows a long time evolution of distributed protocols' technology. Section 3.4 highlighted decentralization via MAS, which has inspired the solutions focused on the

Byzantine Fault Tolerance (BFT) problems [166], discussed around the 1980s, and currently integrates important aspects of Blockchain consensus. Some Byzantine-like variations have been discussed over the years. For instance, the Practical BFT protocol [167] is celebrating 20 years now, and its outcomes have inspired Blockchain world consensus such as the Delegated BFT used by the NEO Blockchain [160].

Moreover, blockchains are also recognized by different network governance levels that imply how the ledger read/write access is made. This gets a classification from permissioned to permissionless, i.e., from more centralized to decentralized network, and it is used to compose a range of Blockchain platforms. Besides the more well known such as the NEO, EOS, Ethereum, and Bitcoin, there are other relevant platforms that focus the most on industrial applications of permissioned chains. Among them, we highlight that the NEO Blockchain is a pioneer high-performance library for developing smart contracts. It was the first Blockchain project to successfully run a public chain with the finality of one block. This means that information appending is finalized as soon as the majority of those involved in the consensus signed the information.

The diverse platforms available meet specific business application needs [168]. As a result, there are several DApps under development that cover the future transportation system, the electricity grid, and a variety of other service applications. For instance, considering smart grids [169], it is possible to manage Electric Vehicle (EV) recharging stations of different energy suppliers through a standard method of payment [170], in which the flow of money and service (the core of the IoV) would flow according to predefined rules. In addition, the use of cryptocurrencies to pay energy bills [171,172] or to trade electricity between citizens with a dedicated Blockchain platform [170,171,173] has the potential to expand the offer of different energy resources for fueling transportation needs.

Therefore, blockchain technology can be seen as a unique and innovative solution for everything that concerns trust between entities, which is reality in almost all interactions of public and private transportation systems. However, decision makers need to increase their awareness that the development of digital technology at a country-level scale may go at its own pace with respect to legal statements and partnerships to deal with the complexity of DLTs [174].

Ultimately, an example of a brief note on a Smart Contract developed in C# can be seen in Figure 4. Basically, this contract, designed for a service called *FutureCitiesTransportationService*, could have the following functions (not limited to): *registerDriver*, *registerPassenger*, *setPassengerCheckpoint*, *getPassengerCheckpointsPrice*, *passengerPay*, *registerAndUpdatePaymentMethod* and *getTokenRate*. Function *registerDriver* could be able to register drivers of the service, while function *registerPassenger* could be public calling for all passengers that wish to use such service. When boarded onto the transportation, automatically, this system could call *setPassengerCheckpoint* for each bus stop the passenger has passed through. When leaving the service, automatically, the price would be shown to the passenger by calling the function *getPassengerCheckpointsPrice*, which the passenger would sign and pay by calling *passengerPay*. The payment could be done by any token listed with *registerAndUpdatePaymentMethod* and obtained with current rates of exchange calling function *getTokenRate*. It should be noticed that *setPassengerCheckpoint* could be anonymous in terms of which passenger is taking the route, in order to avoid leaks or privacy invasion. However, if the passenger did not pay its debt, that data could be decrypted in order to expose the pending amount to be payed.

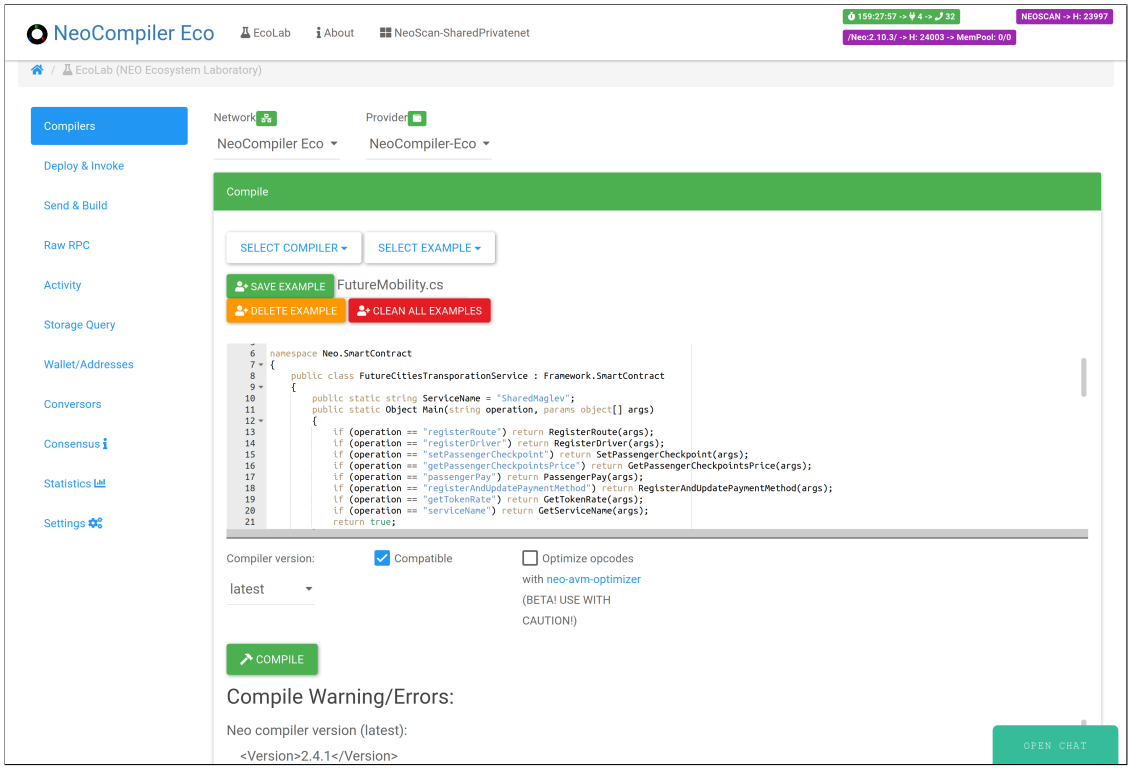


Figure 4. A draft of some functions that could be called for registering operations on the NEO Blockchain, designed with the assistance of https://neocompiler.io.

3.5.2. Removing the Trust Barrier

As aforementioned, blockchain inspired technologies have been emerging as a mechanism for promoting transparency and reducing costs through the distribution of responsibilities and resources to manage an informational network. The advance in the use of personal data to foster business strategies has been gaining attention for a couple of years [175] because of trade-offs between private profitability, social well-being and public awareness about individual life data. Although users' motion data have been important to offer novel transportation options, the way we interact with this data and reach agreements still requires third parties. Turning the latter into a transparent layer is one of the main possibilities of DApps.

Besides the good practices governments have been proposing to handle these issues [175], the Blockchain technology has been seen as a good solution [176,177] for empowering citizens over their data control (self-sovereign identities) and promote reliable cities' transportation systems. For instance, instead of each application collecting user's personal data to manage their transport system, and acting individually to try to satisfy their clients' motion around, the DApps can privately share individual motion data between several transportation systems in order to allow a better data management. This data sharing would be enabled only by specific users' digital signatures over the piece of information they agree to share.

Considering these points, Blockchain appears as a new trend in the area of urban management, balancing data control and flow of money between parties (as will be detailed in Section 3.5.4). Thus, its use opens a completely new mindset where fully-distributed solutions are feasible. In addition to strengthening the use of more competitive tools, the population should be conscious about the possibilities of interacting with intelligent cities' systems, as well as being aware of the data that is being measured and stored. Blockchain based technologies are a disruptive manner of balancing efficiency and trust regarding the use of data measured inside cities'. In addition, such systems have been advocated as more robust and resilient, as well as censorship resistance, which are desirable components for public transportation systems.

These fully distributed systems are able to interact with cryptocurrencies and the services they provide, promoting the emergence of a true IoV. For example, social car pulling could be done by means of automatic smart contracts, which would surely increase transparency and reduce administrative costs. These platforms that contain personalized virtual machine environment comes as an alternative for providing infrastructure to several new startup projects [178].

3.5.3. The Potential of 5G and V2X

While Blockchain contracts may operate offchain [179] and then be published on a public or private chain, the need for a more robust and efficient internet connection is evident [180]. In this sense, we highlight how the concept of Vehicle-to-Everything (V2X) intersects with 5G evolution as a core component of cities' communication [181,182].

By decentralizing transportation, more sophisticated communication paradigms may emerge, in which information can be accessed throughout a swarm of devices. Aligned with Dedicated Short Range Communications (DSRC) [183], this mesh of a vehicular network can surely contribute with the core concepts of Blockchain consensus mechanisms, in which an MAS of vehicles, drones and smartphones would interact with the network. An intersection of these concepts is the Cellular V2X protocol [184], which appears to be suitable for several real applications in the cities' transportation scenario [185]. Besides the efficiency and robustness that such systems may offer, DSRC technology can be more cost-effective than the traditional concept of expanding cellular communication networks [186]. Blockchain technology enabled via V2X DSRC can provide to users a new level of experience in making business and interacting with the financial world. For instance, Jaguar Land Rover recently commented about a partnership with IOTA for cryptocurrency earning when driving their cars [187] via cars' smart wallets. This kind of incentive is interesting and can also be applied on self-organized social systems, such as embedding on platforms such as Waze, Maps.me, among others. In this sense, these same kinds of incentives may appear in such self-organized systems focused on the relationship between users when navigating throughout the cities.

3.5.4. Applications for Carpooling and Ride-Sharing

Along with the advance of novel technologies, new interactive ways of transportation have emerged such as carpooling and ride-sharing, which changes the traditional format of getting around inside the cities [188]. A new range of users has been engaged in these new forms of transportation while new applications arose. With such technologies, we have the possibility of sharing destination, costs and personalizing our trip in a much easier way. Furthermore, it shows up as the first time in the modern society in which P2P online transportation [189] emerges in the concept of IoV .

On the users' side, it gives them the possibility of choosing their preferences about routes and even car models [190], such as opting for a ride-sharing with an electric car, e-scooters or motorcycles and bikes. For example, a given person can even ride a vehicle in a given street street and left it in another random point or station. These decentralized transportation systems are beneficial due to the volume of cars on the runway, being useful in the peak hours, during parking, reducing congestion and, in a sustainable view, reducing pollution [191,192]. Summed up with the possibility of learning from the data [193], these decentralized methodologies gain a huge potential to provide profits to service providers.

Usually, this carpooling and ride-sharing are offered by dedicated online platforms, in mobile applications and websites [194]. In this sense, this type of transport can be seen as a flexible and tailored solution that solves a wide dimension of transport problems [191]. In connection with this line of reasoning, we can say that the evolution of these systems is related to DLT technologies and DApps. There is an open field of privacy concerns, transparency and digital payments that will cross its roots with such applications. In this sense, we believe that integration of such decentralized transportation system will soon have an intersection with cryptocurrencies and smart contracts. The flow of payments between users and those who offer the service should be more automatic, offering rules that are clear to

both sides. In this sense, those who offer the service would not control identities and money anymore, they would be just a channel (a book of offers) in which services would flow a negotiation protocol with rules guided by smart contracts.

4. Final Remarks

4.1. Final Considerations

The academy and the industry have been directing their efforts in a race to improve urban environments, but this transition will have no meaning if the goals and desires of the citizens are not considered. In particular, the industry focuses on competitiveness and, for achieving better profits and a more wide public, the technologies and trends described in this paper can be seen as a must read manual. One of the key points of living in cities' turbulent environments is obviously related to mobility, as highlighted in the survey of Barbosa et al. [195]. In this sense, society is facing the opportunity of guiding the evolution of one of the most immense sets of machines ever built, the urban cities. Evolving and building new urban centers adequately are extremely important for building efficiently designed systems that will be the pillars for future generations. Besides promoting the use of renewable resources, and their interaction with classic urban logistics problems, solutions that rely on digital technologies can boost a better quality of life.

In this paper, recent trends towards autonomous transportation systems for the future Digital and Smart Cities were discussed. The insertion of emerging transportation systems into the current cities requires a strategical, comprehensive, operational and technical analysis. In particular, state-of-the-art optimization methods should be considered and embedded into the best available high performance computers in order to process the huge amount of data currently available both for private and public interests. The potential of Smart Contracts designed with DLTs was particularly highlighted along this study, detailing how decentralized transportation systems could be profitable and more transparent for service providers and users. However, studies in the literature have been showing that new technologies still face challenges in terms of skeptcism. For instance, the distrust of V2G has been shown to be highly prevalent in a study in the Nordic region [196]. This is one of the main reasons that we believe that studies, such as the one conducted throughout this paper, have a great potential for triggering cities' transformation.

This study recapitulates that, once considering the inclusion of novel technologies, it is quite relevant to determine the impacts it may promote. Besides that, it is important to have in mind that each context has a specificity and may respond to the introduction of technologies differently. In this sense, combining strategies that promote social development and also looking toward a more effective and efficient urban environment are essential. For this reason, the renewal of cities' transportation should be assisted by devices able to perform multi-criteria analysis and solve complex problems, considering citizens' perspectives.

4.2. Future Research Directions

Focusing on the use of CI techniques is promising for an efficient and sustainable advancement of cities. The potential of the use of these tools should be emphasized, which can be able to: reduce operational costs; improve various services offered in urban environments; promote fairer and more balanced systems; contrast long-term planning models with efficient solutions that process real-time data; and, in summary, increase the quality of life and human wellbeing. By considering state-of-the-art optimization tools, such as metaheuristic based algorithms [197–200], along with high-performance computing architectures, a sea of data measured by intelligent devices can be mined, processed, learned, predicted and integrated in the search of optimized solutions for our cities.

Studying, designing and developing these systems have a great potential to provide sustainable services, improve services quality and raise awareness about the different possibilities that new technologies are enabling. In this sense, the authors would like to reiterate that there is still a family

of open problems that the new generation may work on. In addition, classical problems which were commonly handled as single objectives, and optimized based on a specific metric, may still have research potential. We believe that this potential is mostly due to how humans adjust their vision on their needs; thus, new tools have emerged and, in consequence, brought to society new possibilities to think about. The need for designing solutions that are more friendly and promote a sustainable urban environment are not only citizens' wishes but also tools with the potential for reducing companies' costs and enhancing their profits. The latter happens because when society wishes changes the economy model behind it is also transformed, proportioning a new path for being optimized in order to attend the needs of the modern transportation systems.

Finally, the implementation of platforms that promote the decentralization of trust in the context of cities' transportation will surely change the way we are interacting with the emerging P2P transportation systems.

Author Contributions: The group of authors contain researchers with a variety of backgrounds, from applied computers scientists to specialists in business and social science. Some authors are closely connected with each other, which have been collaborating with brilliant scientists from Brazil, Spain, Israel and France, co-authors of this paper. Physicists were able to connect this study with state-of-the-art concepts of cutting-edge batteries while computer scientists gave the touch of computational intelligence and high-performance computing. The integration of transportation system is considered with contributions from control and automation engineers while integration with citizens and possibilities of blockchain technologies are handled by those engaged in the field of social sciences and also contributors of different open-source blockchain projects. We believe that our team represents the current possibilities that a globalized world and the future internet can offer, in which science is worldwide and can share visions from different cultures and ideologies, giving light to society while instigating readers with peculiar questions and answers. All authors have read and agreed to the published version of the manuscript.

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Abbreviations

The following abbreviations are used in this manuscript:

CI	Computational Intelligence
BFT	Byzantine Fault Tolerance
DApps	Decentralized Applications
DER	Distributed Energy Resources
DLT	Distributed Ledger Technologies
DSRC	Dedicated Short Range Communications
EV	Electric Vehicle
ICT	Information and Communication Technologies
IoT	Internet of Things
IoV	Internet of Value
MAS	Multi Agent Systems
MCCP	Minimum Coloring Cut Problem
P2P	Peer-to-peer
SC	Smart Cities
SMES	Superconductive Magnetic Energy Storage

SQUID	Superconducting Quantum Interference Device
UAV	Unmanned Aerial Vehicle
V2G	Vehicle-to-Grid
V2X	Vehicle-to-Everything
VRP	Vehicle Routing Problems

References

1. Shetty, V. A tale of smart cities. *Commun. Int.* **1997**, *24*, 16.
2. Sarvapali, D.; Ramchurn, D.H.; Jennings, N.R. Trust in multi-agent systems. *Knowl. Eng. Rev.* **2004**, *19*, 1–25.
3. Benenson, I. Multi-agent simulations of residential dynamics in the city. *Comput. Environ. Urban Syst.* **1998**, *22*, 25–42. [CrossRef]
4. Schaffers, H.; Komninos, N.; Pallot, M.; Trousse, B.; Nilsson, M.; Oliveira, A. Smart cities and the future internet: Towards cooperation frameworks for open innovation. In *The Future Internet Assembly*; Springer: Berlin, Germany, 2011; pp. 431–446.
5. Sun, Y.; Song, H.; Jara, A.J.; Bie, R. Internet of things and big data analytics for smart and connected communities. *IEEE Access* **2016**, *4*, 766–773. [CrossRef]
6. Lawler, E.L.; Lenstra, J.K.; Kan, A.R.; Shmoys, D.B. *The Traveling Salesman Problem: A Guided Tour of Combinatorial Optimization*; Wiley: Hoboken, NJ, USA, 1985.
7. Colorni, A.; Dorigo, M.; Maffioli, F.; Maniezzo, V.; Righini, G.; Trubian, M. Heuristics from nature for hard combinatorial problems. *Int. Trans. Oper. Res.* **1996**, *3*, 1–21. [CrossRef]
8. Triantaphyllou, E. Multi-criteria decision-making methods. In *Multi-Criteria Decision-Making Methods: A Comparative Study*; Springer: Berlin, Germany, 2000; pp. 5–21.
9. Samaniego, H.; Moses, M.E. Cities as organisms: Allometric scaling of urban road networks. *J. Trans. Land Use* **2008**, *1*, 21–39. [CrossRef]
10. Fowke, R.; Prasad, D.K. Sustainable development, cities and local government: Dilemmas and definitions. *Aust. Plan.* **1996**, *33*, 61–66. [CrossRef]
11. Roseland, M. *Toward Sustainable Communities: Solutions for Citizens and Their Governments*, 4th ed.; New Society Publishers: Gabriola Island, BC, Canada, 2012.
12. Campbell, S. Green cities, growing cities, just cities?: Urban planning and the contradictions of sustainable development. *J. Am. Plan. Assoc.* **1996**, *62*, 296–312. [CrossRef]
13. Sun, J.; Yan, J.; Zhang, K.Z. Blockchain-based sharing services: What blockchain technology can contribute to smart cities. *Financ. Innov.* **2016**, *2*, 26. [CrossRef]
14. Soriano, F.R.; Samper-Zapater, J.J.; Martinez-Dura, J.J.; Cirilo-Gimeno, R.V.; Plume, J.M. Smart Mobility Trends: Open Data and Other Tools. *IEEE Intell. Transp. Syst. Mag.* **2018**, *10*, 6–16. doi:10.1109/MITS.2017.2743203. [CrossRef]
15. Yin, C.; Xiong, Z.; Chen, H.; Wang, J.; Cooper, D.; David, B. A literature survey on smart cities. *Sci. China Inf. Sci.* **2015**, *58*, 1–18. [CrossRef]
16. Zhuhadar, L.; Thrasher, E.; Marklin, S.; de Pablos, P.O. The next wave of innovation-Review of smart cities intelligent operation systems. *Comput. Hum. Behav.* **2017**, *66*, 273–281. [CrossRef]
17. Zanella, A.; Bui, N.; Castellani, A.; Vangelista, L.; Zorzi, M. Internet of Things for Smart Cities. *IEEE Internet Things J.* **2014**, *1*, 22–32. doi:10.1109/JIOT.2014.2306328. [CrossRef]
18. Antonopoulos, A. The Internet of Money. Available online: https://www.bortzmeyer.org/internet-of-money.pdf (accessed on 25 January 2020).
19. Lynch, D.C.; Lundquist, L. *Digital Money: The New Era of Internet Commerce*; Wiley: Hoboken, NJ, USA, 1996.
20. Buterin, V. On public and private blockchains. *Ether. Blog*, 6 August 2015.
21. Derrible, S.; Kennedy, C. Applications of Graph Theory and Network Science to Transit Network Design. *Transp. Rev.* **2011**, *31*, 495–519. doi:10.1080/01441647.2010.543709. [CrossRef]
22. Pollio, V. *Vitruvius: The Ten Books on Architecture*; Harvard University Press: Cambridge, MA, USA, 1914.
23. Quercia, D.; Schifanella, R.; Aiello, L.M.; McLean, K. Smelly maps: the digital life of urban smellscapes. *arXiv* **2015**, arXiv:1505.06851.
24. Parkin, J.; Smithies, N. Accounting for the needs of blind and visually impaired people in public realm design. *J. Urban Des.* **2012**, *17*, 135–149. [CrossRef]

25. Martins, I.C.; Pinheiro, R.G.; Protti, F.; Ochi, L.S. A hybrid iterated local search and variable neighborhood descent heuristic applied to the cell formation problem. *Expert Syst. Appl.* **2015**, *42*, 8947–8955. doi:10.1016/j.eswa.2015.07.050. [CrossRef]
26. Bastos, L.; Ochi, L.S.; Protti, F.; Subramanian, A.; Martins, I.C.; Pinheiro, R.G.S. Efficient algorithms for cluster editing. *J. Comb. Optim.* **2016**, *31*, 347–371. doi:10.1007/s10878-014-9756-7. [CrossRef]
27. Chebbi, O.; Nouri, N. Reducing Energy Consumption in Smart Cities: A Scatter Search Based Approach. In Proceedings of the 2016 on Genetic and Evolutionary Computation Conference Companion, Denver, CO, USA, 20–24 July 2016; pp. 1459–1460. doi:10.1145/2908961.2931637. [CrossRef]
28. Lillo, F.; Schmidt, F. Optimal Paths in Real Multimodal Transportation Networks: An Appraisal Using GIS Data from New Zealand and Europe. Available online: https://www.researchgate.net/profile/Felipe_Lillo4/publication/268400265_Optimal_Paths_in_Real_Multimodal_Transportation_Networks_An_Appraisal_Using_GIS_Data_from_New_Zealand_and_Europe/links/5696489c08ae1c4279038b1d.pdf (accessed on 26 January 2020).
29. Silva, J.; Rampazzo, P.B.; Yamakami, A. Urban Mobility in Multi-Modal Networks Using Multi-Objective Algorithms. In *Smart and Digital Cities*; Springer: Berlin, Germany, 2019; pp. 9–22.
30. Völkel, T.; Weber, G. RouteCheckr: personalized multicriteria routing for mobility impaired pedestrians. In Proceedings of the 10th International ACM SIGACCESS Conference on Computers and Accessibility, Halifax, NS, Canada, 13–15 October 2008; pp. 185–192.
31. Golden, B.L.; Assad, A.A.; Levy, L.; Gheysens, F. The fleet size and mix vehicle routing problem. *Comput. Oper. Res.* **1984**, *11*, 49–66. [CrossRef]
32. Or, I. Traveling Salesman-Type Combinational Problems and Their Relation to the Logistics of Blood Banking. Ph.D. Thesis, Northwestern University, Evanston, IL, USA, 1976.
33. Koochaksaraei, H.R.; Enayatifar, R.; Guimarães, F.G. A New Visualization Tool in Many-Objective Optimization Problems. In *Hybrid Artificial Intelligent Systems*; Springer: Berlin, Germany, 2016; pp. 213–224.
34. Koochaksaraei, R.H.; Meneghini, I.R.; Coelho, V.N.; Guimaraes, F.G. A new visualization method in many-objective optimization with chord diagram and angular mapping. *Knowl.-Based Syst.* **2017**, *138*, 134–154. doi:10.1016/j.knosys.2017.09.035. [CrossRef]
35. Dotoli, M.; Zgaya, H.; Russo, C.; Hammadi, S. A Multi-Agent Advanced Traveler Information System for Optimal Trip Planning in a Co-Modal Framework. *IEEE Trans. Intell. Transp. Syst.* **2017**, *PP*, 1–16. doi:10.1109/TITS.2016.2645278. [CrossRef]
36. Dotoli, M.; Epicoco, N.; Falagario, M. A technique for efficient multimodal transport planning with conflicting objectives under uncertainty. In Proceedings of the 2016 European Control Conference (ECC), Aalborg, Denmark, 29 June–1 July 2016; pp. 2441–2446. doi:10.1109/ECC.2016.7810656. [CrossRef]
37. Peprah, C.; Amponsah, O.; Oduro, C. A system view of smart mobility and its implications for Ghanaian cities. *Sustain. Cities Soc.* **2019**, *44*, 739–747. doi:10.1016/j.scs.2018.10.025. [CrossRef]
38. Ziliaskopoulos, A.; Wardell, W. An intermodal optimum path algorithm for multimodal networks with dynamic arc travel times and switching delays. *Eur. J. Oper. Res.* **2000**, *125*, 486–502. [CrossRef]
39. Sbihi, A.; Eglese, R.W. Combinatorial optimization and Green Logistics. *4OR* **2007**, *5*, 99–116. doi:10.1007/s10288-007-0047-3. [CrossRef]
40. Dekker, R.; Bloemhof, J.; Mallidis, I. Operations Research for green logistics—An overview of aspects, issues, contributions and challenges. *Eur. J. Oper. Res.* **2012**, *219*, 671–679. [CrossRef]
41. Duan, F.; He, X. Multiple Depots Incomplete Open Vehicle Routing Problem Based on Carbon Tax. In *Bio-Inspired Computing—Theories and Applications*; Springer: Berlin, Germany, 2014; pp. 98–107. doi:10.1007/978-3-662-45049-9_17. [CrossRef]
42. Wang, S.; Tao, F.; Shi, Y.; Wen, H. Optimization of Vehicle Routing Problem with Time Windows for Cold Chain Logistics Based on Carbon Tax. *Sustainability* **2017**, *9*, 694. [CrossRef]
43. Sawik, B.; Faulin, J.; Pérez-Bernabeu, E. A multicriteria analysis for the green VRP: A case discussion for the distribution problem of a Spanish retailer. *Transp. Res. Procedia* **2017**, *22*, 305–313. [CrossRef]
44. Ubeda, S.; Arcelus, F.; Faulin, J. Green logistics at Eroski: A case study. *Int. J. Prod. Econ.* **2011**, *131*, 44–51. [CrossRef]

45. Gang, H.; Zhijing, G.; Peng, Y.; Junqing, S. Vehicle routing problem with simultaneous pickups and deliveries and time windows considering fuel consumption and carbon emissions. In Proceedings of the 2016 Chinese Control and Decision Conference (CCDC), Yinchuan, China, 28–30 May 2016; pp. 3000–3005. doi:10.1109/CCDC.2016.7531496. [CrossRef]
46. Messaoud, E.; Idrissi, A.E.B.E.; Alaoui, A.E. The green dynamic vehicle routing problem in sustainable transport. In Proceedings of the 2018 4th International Conference on Logistics Operations Management (GOL), Le Havre, France, 10–12 April 2018; pp. 1–6. doi:10.1109/GOL.2018.8378096. [CrossRef]
47. Hardman, S.; Shiu, E.; Steinberger-Wilckens, R. Changing the fate of Fuel Cell Vehicles: Can lessons be learnt from Tesla Motors? *Int. J. Hydrog. Energy* **2015**, *40*, 1625–1638. doi:10.1016/j.ijhydene.2014.11.149. [CrossRef]
48. Rahimi, M.; Baboli, A.; Rekik, Y. Multi-objective inventory routing problem: A stochastic model to consider profit, service level and green criteria. *Transp. Res. Part E: Logist. Transp. Rev.* **2017**, *101*, 59–83. [CrossRef]
49. da Silva, A.R.V.; Ochi, L.S. An efficient hybrid algorithm for the Traveling Car Renter Problem. *Expert Syst. Appl.* **2016**, *64*, 132–140. doi:10.1016/j.eswa.2016.07.038. [CrossRef]
50. Doppstadt, C.; Koberstein, A.; Vigo, D. The Hybrid Electric Vehicle—Traveling Salesman Problem. *Eur. J. Oper. Res.* **2016**, *253*, 825–842. doi:10.1016/j.ejor.2016.03.006. [CrossRef]
51. Dunham, B.; Fridshal, D.; Fridshal, R.; North, J.H. Design by natural selection. *Synthese* **1963**, *15*, 254–259. doi:10.1007/BF00484855. [CrossRef]
52. Xu, J.; Zhang, J. Exploration-exploitation trade-offs in metaheuristics: Survey and analysis. In Proceedings of the 33rd Chinese Control Conference, Nanjing, China, 28–30 July 2014; pp. 8633–8638.
53. Woeginger, G.J. Exact algorithms for NP-hard problems: A survey. In *Combinatorial Optimization—Eureka, You Shrink!*; Springer: Berlin, Germany, 2003; pp. 185–207.
54. Kitchin, R. The real-time city? Big data and smart urbanism. *GeoJournal* **2014**, *79*, 1–14. [CrossRef]
55. Nemhauser, G.L.; Wolsey, L.A. Integer programming and combinatorial optimization. In Proceedings of the IPCO: International Conference on Integer Programming and Combinatorial Optimization, Houston, TX, USA, 22–24 June 1998.
56. Coelho, V.N.; Coelho, I.M.; Souza, M.J.F.; Oliveira, T.A.; Cota, L.P.; Haddad, M.N.; Mladenovic, N.; Silva, R.C.P.; Guimaraes, F.G. Hybrid Self-Adaptive Evolution Strategies Guided by Neighborhood Structures for Combinatorial Optimization Problems. *Evol. Comput.* **2016**, *24*, 637–666. doi:10.1162/EVCO_a_00187. [CrossRef]
57. Johnson, D.S.; Papadimitriou, C.H.; Yannakakis, M. How easy is local search? *J. Comput. Syst. Sci.* **1988**, *37*, 79–100. [CrossRef]
58. Schulz, C. Efficient local search on the GPU—Investigations on the vehicle routing problem. *J. Parallel Distrib. Comput.* **2013**, *73*, 14–31. [CrossRef]
59. Szymon, J.; Dominik, Ż. Solving multi-criteria vehicle routing problem by parallel tabu search on GPU. *Procedia Comput. Sci.* **2013**, *18*, 2529–2532. [CrossRef]
60. Sguglio, A.; Arcuri, N.; Bruno, R. Integration of Social Science in Engineering Research for Smart Cities. The Italian Case of the RES NOVAE Project. In Proceedings of the 2018 IEEE International Conference on Environment and Electrical Engineering and 2018 IEEE Industrial and Commercial Power Systems Europe (EEEIC / I CPS Europe), Palermo, Italy, 12–15 June 2018. doi:10.1109/EEEIC.2018.8493774. [CrossRef]
61. Want, R. Remembering Mark Weiser: Chief Technologist, Xerox Parc. *IEEE Pers. Commun.* **2000**, *7*, 8–10. doi:10.1109/MPC.2000.824564. [CrossRef]
62. Russell, S.J.; Norvig, P. *Artificial Intelligence: A Modern Approach*; Pearson: London, UK, 2016.
63. Nigon, J.; Glize, E.; Dupas, D.; Crasnier, F.; Boes, J. Use cases of pervasive artificial intelligence for smart cities challenges. In Proceedings of the 2016 Intl IEEE Conferences on Ubiquitous Intelligence & Computing, Advanced and Trusted Computing, Scalable Computing and Communications, Cloud and Big Data Computing, Internet of People, and Smart World Congress (UIC/ATC/ScalCom/CBDCom/IoP/SmartWorld), Toulouse, France, 18–21 July 2016.
64. Oliveira, T.A.; Barbosa, A.C.; Ramalhinho, H.; Oliver, M. Citizens and Information and Communication Technologies. In Proceedings of the 2018 International Joint Conference on Neural Networks (IJCNN), Rio de Janeiro, Brazil, 8–13 July 2018. doi:10.1109/IJCNN.2018.8489031. [CrossRef]
65. Oliveira, T.A.; Coelho, V.N.; Tavares, W.; Ramalhinho, H.; Oliver, M. Desafios operacionais e digitais para conectar cidadãos em cidades inteligentes. Available online: http://www.sbpo2017.iltc.br/pdf/170636.pdf (accessed on 26 January 2020).

66. Oliveira, T.A.; Coelho, V.N.; Ramalhinho, H.; Oliver, M. Digital Cities and Emerging Technologies. In *Smart and Digital Cities*; Springer: Berlin, Germany, 2019; pp. 197–207.
67. Dobrovnik, M.; Herold, D.; Fürst, E.; Kummer, S. Blockchain for and in Logistics: What to Adopt and Where to Start. *Logistics* **2018**, *2*, 18. [CrossRef]
68. Kshetri, N. Can blockchain strengthen the internet of things? *IT Prof.* **2017**, *19*, 68–72. [CrossRef]
69. Kahrobaee, S.; Rajabzadeh, R.A.; Soh, L.K.; Asgarpoor, S. Multiagent study of smart grid customers with neighborhood electricity trading. *Electr. Power Syst. Res.* **2014**, 123–132. doi:10.1016/j.epsr.2014.02.013. [CrossRef]
70. Merabet, G.; Essaaidi, M.; Talei, H.; Abid, M.; Khalil, N.; Madkour, M.; Benhaddou, D. Applications of Multi-Agent Systems in Smart Grids: A survey. In Proceedings of the Multimedia Computing and Systems (ICMCS), Marrakech, Morocco, 14–16 April 2014; pp. 1088–1094. doi:10.1109/ICMCS.2014.6911384. [CrossRef]
71. Olivares, D.; Mehrizi-Sani, A.; Etemadi, A.; Canizares, C.; Iravani, R.; Kazerani, M.; Hajimiragha, A.; Gomis-Bellmunt, O.; Saeedifard, M.; Palma-Behnke, R.; et al. Trends in Microgrid Control. *IEEE Trans. Smart Grid* **2014**, *5*, 1905–1919. doi:10.1109/TSG.2013.2295514. [CrossRef]
72. Mengelkamp, E.; Gärttner, J.; Rock, K.; Kessler, S.; Orsini, L.; Weinhardt, C. Designing microgrid energy markets: A case study: The Brooklyn Microgrid. *Appl. Energy* **2018**, *210*, 870–880. [CrossRef]
73. Park, S.; Lee, J.; Bae, S.; Hwang, G.; Choi, J.K. Contribution-based energy-trading mechanism in microgrids for future smart grid: A game theoretic approach. *IEEE Trans. Ind. Electron.* **2016**, *63*, 4255–4265. [CrossRef]
74. Zhu, T.; Huang, Z.; Sharma, A.; Su, J.; Irwin, D.; Mishra, A.; Menasche, D.; Shenoy, P. Sharing renewable energy in smart microgrids. In Proceedings of the C2013 ACM/IEEE International Conference on Cyber-Physical Systems (ICCPS), Philadelphia, PA, USA, 8–11 April 2013; pp. 219–228.
75. Liu, J.; Li, Q.; Qu, M.; Chen, W.; Yang, J.; Xiong, H.; Zhong, H.; Fu, Y. Station Site Optimization in Bike Sharing Systems. In Proceedings of the 2015 IEEE International Conference on Data Mining, Atlantic City, NJ, USA, 14–17 November 2015; pp. 883–888. doi:10.1109/ICDM.2015.99. [CrossRef]
76. Frade, I.; Ribeiro, A. Bike-sharing stations: A maximal covering location approach. *Transp. Res. Part A: Policy Pract.* **2015**, *82*, 216–227. doi:10.1016/j.tra.2015.09.014. [CrossRef]
77. Maggioni, F.; Cagnolari, M.; Bertazzi, L.; Wallace, S.W. Stochastic optimization models for a bike-sharing problem with transshipment. *Eur. J. Oper. Res.* **2019**, *276*, 272–283. doi:10.1016/j.ejor.2018.12.031. [CrossRef]
78. Ji, S.; Cherry, C.R.; Han, L.D.; Jordan, D.A. Electric bike sharing: Simulation of user demand and system availability. *J. Clean. Prod.* **2014**, *85*, 250–257. doi:10.1016/j.jclepro.2013.09.024. [CrossRef]
79. Rose, G.; Delbosc, A. Powered-two-wheelers for city commuting: Insight from Australia's three largest capital cities. *J. Trans. Geogr.* **2016**, *54*, 325–335. doi:10.1016/j.jtrangeo.2016.05.019. [CrossRef]
80. Hardt, C.; Bogenberger, K. Usage of e-scooters in urban environments. *Transp. Res. Procedia* **2019**, *37*, 155–162. doi:10.1016/j.trpro.2018.12.178. [CrossRef]
81. Wild, K.; Woodward, A. Why are cyclists the happiest commuters? Health, pleasure and the e-bike. *J. Transp. Health* **2019**, *14*, 100569. doi:10.1016/j.jth.2019.05.008. [CrossRef]
82. Thoreau, R. The impact of mobility scooters on their users. Does their usage help or hinder?: A state of the art review. *J. Transp. Health* **2015**, *2*, 269–275. doi:10.1016/j.jth.2015.03.005. [CrossRef] [PubMed]
83. May, E.; Garrett, R.; Ballantyne, A. Being mobile: Electric mobility-scooters and their use by older people. *Ageing Soc.* **2010**, *30*, 1219–1237. doi:10.1017/S0144686X10000334. [CrossRef]
84. Nocerino, R.; Colorni, A.; Lia, F.; Luè, A. E-bikes and E-scooters for smart logistics: Environmental and economic sustainability in pro-E-bike Italian pilots. *Transp. Res. Procedia* **2016**, *14*, 2362–2371. doi:10.1016/j.trpro.2016.05.267. [CrossRef]
85. Tasseron, G.; Martens, K. Urban parking space reservation through bottom-up information provision: An agent-based analysis. *Comput. Environ. Urban Syst.* **2017**, *64*, 30–41. doi:10.1016/j.compenvurbsys.2017.01.002. [CrossRef]
86. Ji, Z.; Ganchev, I.; O'Droma, M.; Zhao, L.; Zhang, X. A cloud-based car parking middleware for IoT-based smart cities: Design and implementation. *Sensors* **2014**, *14*, 22372–22393. [CrossRef]
87. Ganchev, I.; O'Droma, M.; Meere, D. Intelligent car parking locator service. *Int. J.* **2008**, *2*, 166–173.
88. Grodi, R.; Rawat, D.B.; Rios-Gutierrez, F. Smart parking: Parking occupancy monitoring and visualization system for smart cities. In Proceedings of the SoutheastCon 2016, Norfolk, VA, USA, 30 March–3 April 2016; pp. 1–5. doi:10.1109/SECON.2016.7506721. [CrossRef]

89. Coelho, V.N.; Coelho, I.M.; Coelho, B.N.; Cohen, M.W.; Reis, A.J.; Silva, S.M.; Souza, M.J.; Fleming, P.J.; Guimaraes, F.G. Multi-objective energy storage power dispatching using plug-in vehicles in a smart-microgrid. *Renew. Energy* **2016**, *89*, 730–742. doi:10.1016/j.renene.2015.11.084. [CrossRef]
90. Wolfram, P.; Lutsey, N. Electric vehicles: Literature review of technology costs and carbon emissions. In Proceedings of the International Council on Clean Transportation, Washington, DC, USA, 15 July 2016.
91. Nordelöf, A.; Messagie, M.; Tillman, A.M.; Söderman, M.L.; Van Mierlo, J. Environmental impacts of hybrid, plug-in hybrid, and battery electric vehicles—What can we learn from life cycle assessment? *Int. J. Life Cycle Assess.* **2014**, *19*, 1866–1890. [CrossRef]
92. Agha, A.; Ranjan, R.; Gan, W.S. Noisy vehicle surveillance camera: A system to deter noisy vehicle in smart city. *Appl. Acoust.* **2017**, *117*, 236–245. doi:10.1016/j.apacoust.2016.05.025. [CrossRef]
93. Coelho, V.N.; Cohen, M.W.; Coelho, I.M.; Liu, N.; Guimarães, F.G. Multi-agent systems applied for energy systems integration: State-of-the-art applications and trends in microgrids. *Appl. Energy* **2017**, *187*, 820–832. doi:10.1016/j.apenergy.2016.10.056. [CrossRef]
94. Di Napoli, C.; Di Nocera, D.; Rossi, S. Using Negotiation for Parking Selection in Smart Cities. In Proceedings of the International Conference on Practical Applications of Agents and Multi-Agent Systems, Salamanca, Spain, 4–6 June 2014; Springer: Berlin, Germany, 2014; pp. 331–334. doi:10.1007/978-3-319-07551-8_31. [CrossRef]
95. Longo, M.; Roscia, M.; Lazaroiu, G.C. Innovating Multi-agent Systems Applied to Smart City. *Res. J. Appl. Sci. Eng. Technol.* **2014**, *7*, 4296–4302. doi:10.19026/rjaset.7.801. [CrossRef]
96. Battistelli, C.; Baringo, L.; Conejo, A. Optimal energy management of small electric energy systems including {V2G} facilities and renewable energy sources. *Electr. Power Syst. Res.* **2012**, *92*, 50–59. doi:10.1016/j.epsr.2012.06.002. [CrossRef]
97. Kempton, W.; Tomić, J. Vehicle-to-grid power fundamentals: Calculating capacity and net revenue. *J. Power Sources* **2005**, *144*, 268–279. [CrossRef]
98. Coelho, V.N.; Coelho, I.M.; Coelho, B.N.; de Oliveira, G.C.; Barbosa, A.C.; Pereira, L.; de Freitas, A.; Santos, H.G.; Ochi, L.S.; Guimarães, F.G. A communitarian microgrid storage planning system inside the scope of a smart city. *Appl. Energy* **2017**, *201*, 371–381. doi:10.1016/j.apenergy.2016.12.043. [CrossRef]
99. Saber, A.Y.; Venayagamoorthy, G.K. Intelligent unit commitment with vehicle-to-grid—A cost-emission optimization. *J. Power Sources* **2010**, *195*, 898–911. [CrossRef]
100. García-Magariño, I.; Palacios-Navarro, G.; Lacuesta, R.; Lloret, J. ABSCEV: An agent-based simulation framework about smart transportation for reducing waiting times in charging electric vehicles. *Comput. Netw.* **2018**, *138*, 119–135. [CrossRef]
101. Hu, J.; Saleem, A.; You, S.; Nordström, L.; Lind, M.; Østergaard, J. A multi-agent system for distribution grid congestion management with electric vehicles. *Eng. Appl. Artif. Intell.* **2015**, *38*, 45–58. [CrossRef]
102. Lin, C.; Choy, K.; Ho, G.; Chung, S.; Lam, H. Survey of Green Vehicle Routing Problem: Past and future trends. *Expert Syst. Appl.* **2014**, *41*, 1118–1138. doi:10.1016/j.eswa.2013.07.107. [CrossRef]
103. Erdoğan, S.; Miller-Hooks, E. A Green Vehicle Routing Problem. *Transp. Res. Part E: Logist. Transp. Rev.* **2012**, *48*, 100–114. doi:10.1016/j.tre.2011.08.001. [CrossRef]
104. Gnann, T.; Plotz, P.; Funke, S.; Wietschel, M. What is the market potential of plug-in electric vehicles as commercial passenger cars? A case study from Germany. *Transp. Res. Part D: Transp. Environ.* **2015**, *37*, 171–187. doi:10.1016/j.trd.2015.04.015. [CrossRef]
105. Khaligh, A.; Li, Z. Battery, Ultracapacitor, Fuel Cell, and Hybrid Energy Storage Systems for Electric, Hybrid Electric, Fuel Cell, and Plug-In Hybrid Electric Vehicles: State of the Art. *IEEE Trans. Veh. Technol.* **2010**, *59*, 2806–2814. doi:10.1109/TVT.2010.2047877. [CrossRef]
106. Peters, A. This Bike Path Paved With Solar Panels Shows That All Streets Could Double As Power Sources. Available online: https://www.fastcompany.com/3053585/this-bike-path-paved-with-solar-panels-shows-that-all-streets-could-double-as-power-sources (accessed on 25 January 2020).
107. Gupta, S.G.; Ghonge, M.M.; Jawandhiya, P. Review of unmanned aircraft system (UAS). *Int. J. Adv. Res. Comput. Eng. Technol.* **2013**, *2*, 1646–1658. [CrossRef]
108. Coelho, B.N.; Coelho, V.N.; Coelho, I.M.; Ochi, L.S.; Haghnazar, R.; Zuidema, D.; Lima, M.S.; da Costa, A.R. A multi-objective green UAV routing problem. *Comput. Oper. Res.* **2017**, *88*, 306–315. doi:10.1016/j.cor.2017.04.011. [CrossRef]

109. Sun, L.; Huang, Y.; Liu, S.; Chen, Y.; Yao, L.; Kashyap, A. A completive survey study on the feasibility and adaptation of {EVs} in Beijing, China. *Appl. Energy* **2017**, *187*, 128–139. doi:10.1016/j.apenergy.2016.11.027. [CrossRef]
110. Celik, K.; Eren, H. UAV fuel preferences for future cities. In Proceedings of the 2018 6th International Istanbul Smart Grids and Cities Congress and Fair (ICSG), Istanbul, Turkey, 25–26 April 2018. doi:10.1109/SGCF.2018.8408962. [CrossRef]
111. Nguyen, H.T.; Nishiyama, S.; Izumi, M.; Zheng, L.; Miao, X.; Sakai, Y.; Goto, H.; Hirao, N.; Ohishi, Y.; Kagayama, T.; et al. Fabrication of new superconducting materials, $Ca_xK_{1-x}C_y$ (0 < x< 1). *Carbon* **2016**, *100*, 641–646.
112. Savitskii, E. *Superconducting Materials*; Springer Science & Business Media: Berlin, Germany, 2012.
113. Kolmogorov, A. Theory-Guided Discovery of New Superconducting Materials. Available online: https://ui.adsabs.harvard.edu/abs/2015APS..MARA16001K/abstract (accessed on 26 January 2020).
114. Toida, H.; Matsuzaki, Y.; Kakuyanagi, K.; Zhu, X.; Munro, W.J.; Nemoto, K.; Yamaguchi, H.; Saito, S. Electron paramagnetic resonance spectroscopy using a direct current-SQUID magnetometer directly coupled to an electron spin ensemble. *Appl. Phys. Lett.* **2016**, *108*, 052601. [CrossRef]
115. Liu, X.D.; Jin, J.X.; Wen, L. A Multifunction Measurement Instrument for Applied Superconductor Properties and Applications. *IEEE Trans. Appl. Supercond.* **2016**, *26*, 1–4. [CrossRef]
116. Benz, S.P. Quantum-based voltage metrology with superconducting Josephson devices at NIST. In Proceedings of the Precision Electromagnetic Measurements (CPEM 2016), Ottawa, ON, Canada, 10–15 July 2016.
117. Scurti, F.; Schwartz, J. Optical fiber distributed sensing for high temperature superconductor magnets. In Proceedings of the 2017 25th Optical Fiber Sensors Conference (OFS), Jeju, South Korea, 24–28 April 2017.
118. Chu, C.; Canfield, P.; Dynes, R.; Fisk, Z.; Batlogg, B.; Deutscher, G.; Geballe, T.; Zhao, Z.; Greene, R.; Hosono, H.; et al. Epilogue: Superconducting materials past, present and future. *Phys. C: Supercond. Appl.* **2015**, *514*, 437–443. [CrossRef]
119. Barrentine, E.M.; Noroozian, O.; Brown, A.D.; Cataldo, G.; Ehsan, N.; Hsieh, W.T.; Stevenson, T.R.; U-Yen, K.; Wollack, E.J.; Moseley, S.H. Overview of the Design, Fabrication and Performance Requirements of Micro-Spec, an Integrated Submillimeter Spectrometer. Available online: https://ntrs.nasa.gov/search.jsp?R=20150016073 (accessed on 25 January 2020).
120. Bertola, L.; Cox, T.; Wheeler, P.; Garvey, S. Superconducting and conventional electromagnetic launch system for civil aircraft assisted take-off. In Proceedings of the 2016 IEEE Energy Conversion Congress and Exposition (ECCE), Milwaukee, MI, USA, 18–22 September 2016. doi:10.1109/ECCE.2016.7855477. [CrossRef]
121. Ashtineh, H.; Pishvaee, M.S. Alternative fuel vehicle-routing problem: A life cycle analysis of transportation fuels. *J. Clean. Prod.* **2019**, *219*, 166–182. doi:10.1016/j.jclepro.2019.01.343. [CrossRef]
122. Shaukat, N.; Khan, B.; Ali, S.; Mehmood, C.; Khan, J.; Farid, U.; Majid, M.; Anwar, S.; Jawad, M.; Ullah, Z. A survey on electric vehicle transportation within smart grid system. *Renew. Sustain. Energy Rev.* **2018**, *81*, 1329–1349. doi:10.1016/j.rser.2017.05.092. [CrossRef]
123. Tolpygo, S.K.; Bolkhovsky, V.; Weir, T.; Wynn, A.; Oates, D.; Johnson, L.; Gouker, M. Advanced fabrication processes for superconducting very large-scale integrated circuits. *IEEE Trans. Appl. Supercond.* **2016**, *26*, 1–10. [CrossRef]
124. Snitchler, G. Progress on high temperature superconductor propulsion motors and direct drive wind generators. In Proceedings of the 2010 International Power Electronics Conference—ECCE ASIA, Sapporo, Japan, 21–24 June 2010.
125. Snitchler, G.; Gamble, B.; Kalsi, S.S. The performance of a 5 MW high temperature superconductor ship propulsion motor. *IEEE Trans. Appl. Supercond.* **2005**, *15*, 2206–2209. [CrossRef]
126. Stumberger, G.; Aydemir, M.T.; Zarko, D.; Lipo, T.A. Design of a linear bulk superconductor magnet synchronous motor for electromagnetic aircraft launch systems. *IEEE Trans. Appl. Supercond.* **2004**, *14*, 54–62. [CrossRef]
127. Snitchler, G.; Gamble, B.; King, C.; Winn, P. 10 MW class superconductor wind turbine generators. *IEEE Trans. Appl. Supercond.* **2011**, *21*, 1089–1092. [CrossRef]
128. Lee, H.W.; Kim, K.C.; Lee, J. Review of maglev train technologies. *IEEE Trans. Mag.* **2006**, *42*, 1917–1925.

129. Xu, Y.L.; Wang, Z.L.; Li, G.Q.; Chen, S.; Yang, Y.B. High-speed running maglev trains interacting with elastic transitional viaducts. *Eng. Struct.* **2019**, *183*, 562–578. doi:10.1016/j.engstruct.2019.01.012. [CrossRef]
130. Younis, L.; Al Suhail, A.; Ziai, S.; Sun, L. Connecting the GCC Countries with the Maglev Train. Available online: https://dspace.aus.edu/xmlui/bitstream/handle/11073/7483/HGCCcountries26theMaglevtrain.pdf?sequence=1&isAllowed=y (accessed on 25 January 2020).
131. Anthopoulos, L. Smart utopia VS smart reality: Learning by experience from 10 smart city cases. *Cities* **2017**, *63*, 128–148. [CrossRef]
132. Rothengatter, W. Megaprojects in transportation networks. *Transp. Policy* **2019**, *75*, A1–A15. doi:10.1016/j.tranpol.2018.08.002. [CrossRef]
133. Hossain, M.F. Chapter Five—Infrastructure and Transportation. In *Sustainable Design and Build*; Hossain, M.F., Ed.; Elsevier: Amsterdam, The Netherlands, 2019; pp. 231–300. doi:10.1016/B978-0-12-816722-9.00005-7. [CrossRef]
134. Ali, M.H.; Wu, B.; Dougal, R.A. An overview of SMES applications in power and energy systems. *IEEE Trans. Sustain. Energy* **2010**, *1*, 38–47. [CrossRef]
135. Trevisani, L.; Morandi, A.; Negrini, F.; Ribani, P.L.; Fabbri, M. Cryogenic Fuel-Cooled SMES for Hybrid Vehicle Application. *IEEE Trans. Appl. Supercond.* **2009**, *19*, 2008–2011. doi:10.1109/TASC.2009.2018482. [CrossRef]
136. Xing, Y.Q.; Jin, J.X.; Wang, Y.L.; Du, B.X.; Wang, S.C. An Electric Vehicle Charging System Using an SMES Implanted Smart Grid. *IEEE Trans. Appl. Supercond.* **2016**, *26*, 1–4. doi:10.1109/TASC.2016.2602245. [CrossRef]
137. Furrer+Frey Opbrid Charging Systems. Available online: https://opbrid.info/ (accessed on 26 January 2020).
138. A Giant Charger That Juices Up Electric Buses in Three Minutes | WIRED. Available online: https://www.wired.com/2014/10/giant-charger-juices-electric-buses-three-minutes/ (accessed on 27 June 2017).
139. Lagorse, J.; Simoes, M.; Miraoui, A. A Multiagent Fuzzy-Logic-Based Energy Management of Hybrid Systems. *IEEE Trans. Ind. Appl.* **2009**, *45*, 2123–2129. doi:10.1109/TIA.2009.2031786. [CrossRef]
140. Annaswamy, A.M.; Malekpour, A.R.; Baros, S. Emerging research topics in control for smart infrastructures. *Annu. Rev. Control* **2016**, *42*, 259–270. doi:10.1016/j.arcontrol.2016.10.001. [CrossRef]
141. Shoham, Y.; Leyton-Brown, K. *Multiagent Systems: Algorithmic, Game-Theoretic, and Logical Foundations*; Cambridge University Press: Cambridge, UK, 2008.
142. Postránecký, F.; Svítek, M. Conceptual model of complex multi-agent system smart city 4.0. In Proceedings of the International Conference on Industrial Applications of Holonic and Multi-Agent Systems, Lyon, France, 28–30 August 2017; Springer: Berlin, Germany, 2017; pp. 215–226. doi:10.1007/978-3-319-64635-0_16. [CrossRef]
143. Zambonelli, F. Engineering self-organizing urban superorganisms. *Eng. Appl. Artif. Intell.* **2015**, *41*, 325–332. doi:10.1016/j.engappai.2014.10.004. [CrossRef]
144. Bicocchi, N.; Leonardi, L.; Zambonelii, F. Software-Intensive Systems for Smart Cities: From Ensembles to Superorganisms. In *Software, Services, and Systems*; Springer: Berlin, Germany, 2015; pp. 538–551. doi:10.1007/978-3-319-15545-6_31. [CrossRef]
145. Chen, M. Towards smart city: M2M communications with software agent intelligence. *Multimed. Tool. Appl.* **2013**, *67*, 167–178. doi:10.1007/s11042-012-1013-4. [CrossRef]
146. Marsa-Maestre, I.; Lopez-Carmona, M.A.; Velasco, J.R.; Navarro, A. Mobile agents for service personalization in smart environments. *J. Netw.* **2008**, *3*, 30–41. doi:10.4304/jnw.3.5.30-41. [CrossRef]
147. Mannion, P.; Duggan, J.; Howley, E. Parallel reinforcement learning for traffic signal control. *Procedia Comput. Sci.* **2015**, *52*, 956–961. doi:10.1016/j.procs.2015.05.172. [CrossRef]
148. Prendinger, H.; Gajananan, K.; Zaki, A.B.; Fares, A.; Molenaar, R.; Urbano, D.; van Lint, H.; Gomaa, W. Tokyo virtual living lab: Designing smart cities based on the 3d internet. *IEEE Internet Comput.* **2013**, *17*, 30–38. doi:10.1109/MIC.2013.87. [CrossRef]
149. Bjornskau, T. The Zebra Crossing Game – Using game theory to explain a discrepancy between road user behaviour and traffic rules. *Saf. Sci.* **2017**, *92*, 298–301. doi:10.1016/j.ssci.2015.10.007. [CrossRef]

150. Soares, G.; Kokkinogenis, Z.; Macedo, J.L.; Rossetti, R.J.F. Agent-Based Traffic Simulation Using SUMO and JADE: An Integrated Platform for Artificial Transportation Systems. In Proceedings of the Simulation of Urban MObility User Conference, Berlin, Germany, 15–17 May 2013. doi:10.1007/978-3-662-45079-6_4. [CrossRef]
151. Lämmer, S.; Helbing, D. Self-control of traffic lights and vehicle flows in urban road networks. *J. Stat. Mech.: Theory Exp.* **2008**, *2008*, P04019. [CrossRef]
152. Paruchuri, P.; Pullalarevu, A.R.; Karlapalem, K. Multi agent simulation of unorganized traffic. In Proceedings of the First International Joint Conference on Autonomous Agents and Multiagent Systems: Part 1, Bologna, Italy, 15–19 July 2002.
153. Hernández, R.; Cárdenas, C.; Muõz, D. Game theory applied to transportation systems in Smart Cities: analysis of evolutionary stable strategies in a generic car pooling system. *Int. J. Interact. Des. Manuf.* **2018**, *12*, 179–185. doi:10.1007/s12008-017-0373-4. [CrossRef]
154. Wang, J.; Wang, C.; Song, X.; Raghavan, V. Automatic intersection and traffic rule detection by mining motor-vehicle GPS trajectories. *Comput. Environ. Urban Syst.* **2017**, *64*, 19–29. doi:10.1016/j.compenvurbsys.2016.12.006. [CrossRef]
155. Xie, X.; Liao, W.; Aghajan, H.; Veelaert, P.; Philips, W. A novel approach for detecting intersections from GPS traces. In Proceedings of the 2016 IEEE International Geoscience and Remote Sensing Symposium (IGARSS), Beijing, China, 10–15 July 2016. doi:10.1109/IGARSS.2016.7729466. [CrossRef]
156. D'Andrea, E.; Marcelloni, F. Detection of traffic congestion and incidents from GPS trace analysis. *Expert Syst. Appl.* **2017**, *73*, 43–56. doi:10.1016/j.eswa.2016.12.018. [CrossRef]
157. Qiu, J.; Wang, R.; Wang, X. Inferring road maps from sparsely-sampled GPS traces. *Lect. Note Comput. Sci.* **2014**, *8436*, 339–344. doi:10.1007/978-3-319-06483-3_35. [CrossRef]
158. Sandel, M.J. *Justice: What's the Right Thing to Do?*; Farrar, Straus and Giroux: New York, NY, USA, 2010.
159. Nakamoto, S. Bitcoin: A Peer-to-Peer Electronic Cash System. Available online: https://git.dhimmel.com/bitcoin-whitepaper/ (accessed on 25 January 2020).
160. Da, H.; Zhang, E. NEO: A Distributed Network for the Smart Economy. Available online: https://bravenewcoin.com/insights/neo-white-paper-a-distributed-network-for-the-smart-economy (accessed on 25 January 2020).
161. Perlman, L. Distributed Ledger Technologies and Financial Inclusion. Available online: https://www.itu.int/en/ITU-T/focusgroups/dfs/Documents/201703/ITU_FGDFS_Report-on-DLT-and-Financial-Inclusion.pdf (accessed on 25 January 2020).
162. The Linux Foundation. Blockchain for Business—An Introduction to Hyperledger Technologies. Available online: https://d37djvu3ytnwxt.cloudfront.net/assets/courseware/v1/f78e55f0cfc90346abab4ae5096007d2/asset-v1:LinuxFoundationX+LFS171x+3T2017+type@asset+block@LFS171x_-_Blockchain_for_Business_-_An_Introduction_to_Hyperledger_Technologies_Outline.pdf (accessed on 26 January 2020).
163. Blockchains for Social Good. Available online: https://ec.europa.eu/research/eic/index.cfm?pg=prizes_blockchains (accessed on 26 January 2020).
164. Swan, M. *Blockchain: Blueprint for a New Economy*; O'Reilly Media: Sebastopol, CA, USA, 2015.
165. PwC. Blockchain—An Opportunity for Energy Producers and Consumers? Available online: https://www.pwc.com/gx/en/industries/assets/pwc-blockchain-opportunity-for-energy-producers-and-consumers.pdf (accessed on 25 January 2020).
166. Lamport, L.; Shostak, R.; Pease, M. The Byzantine generals problem. *ACM Trans. Program. Lang. Syst.* **1982**, *4*, 382–401. [CrossRef]
167. Castro, M.; Liskov, B. Practical Byzantine fault tolerance. *OSDI* **1999**, *99*, 173–186.
168. Kandaswamy, R. Blockchain: How Real Is The Market? Available online: https://www.gartner.com/en/site-index (accessed on 25 January 2020).
169. Valtanen, K.; Backman, J.; Yrjölä, S. Blockchain-Powered Value Creation in the 5G and Smart Grid Use Cases. *IEEE Access* **2019**, *7*, 25690–25707. doi:10.1109/ACCESS.2019.2900514. [CrossRef]
170. Merz, M. Potential of the Blockchain Technology in Energy Trading. Available online: http://www.ponton.de/downloads/mm/Potential-of-the-Blockchain-Technology-in-Energy-Trading_Merz_2016.en.pdf (accessed on 25 January 2020).

171. Groarke, D. Utilities and Blockchain Pilots—A Global Snapshot. Available online: https://www.indigoadvisorygroup.com/blog/2016/10/7/utilities-piloting-blockchain-application-globally (accessed on 24 September 2017).
172. Grid Singularity. The Blockchain: Enabling a Distributed and Connected Energy Future. Available online: https://www.youtube.com/watch?v=cpMwPhA9QzM&feature=youtu.be&t=1h33m5s (accessed on 26 January 2020).
173. Power Ledger Whitepaper. Available online: https://cdn2.hubspot.net/hubfs/4519667/Documents/PowerLedgerWhitepaper.pdf (accessed on 25 January 2020).
174. Smolenski, N. BLOCKCHAIN IN GOVERNMENT BRIEFING: Q3 2017. Available online: http://www.learningmachine.com/wp-content/uploads/2017/07/Blockchain-in-Government-2017-Q3.pdf (accessed on 25 January 2020).
175. Council of European Union. Regulation (EU) 2016/679 of the European Parliament and of the Council. Available online: https://eur-lex.europa.eu/eli/reg/2016/679/2016-05-04 (accessed on 25 January 2020).
176. Portier, C.C.M.L.B. Blockchain and GDPR: How Blockchain Could Address Five Areas Associated with GDPR Compliance. Available online: https://www.ibm.com/downloads/cas/2EXR2XYP (accessed on 25 January 2020).
177. Timsit, T.L.L.C.K. Blockchain and the GDPR. Available online: https://www.cnil.fr/en/blockchain-and-gdpr-solutions-responsible-use-blockchain-context-personal-data (accessed on 25 January 2020).
178. Morkunas, V.J.; Paschen, J.; Boon, E. How blockchain technologies impact your business model. *Bus. Horiz.* **2019**, *62*, 295–306. doi:10.1016/j.bushor.2019.01.009. [CrossRef]
179. Di Stasi, G.; Avallone, S.; Canonico, R.; Ventre, G. Routing Payments on the Lightning Network. In Proceedings of the 2018 IEEE International Conference on Internet of Things (iThings) and IEEE Green Computing and Communications (GreenCom) and IEEE Cyber, Physical and Social Computing (CPSCom) and IEEE Smart Data (SmartData), Halifax, NS, Canada, 30 July–3 August 2018. doi:10.1109/Cybermatics_2018.2018.00209. [CrossRef]
180. Xie, L.; Ding, Y.; Yang, H.; Wang, X. Blockchain-Based Secure and Trustworthy Internet of Things in SDN-Enabled 5G-VANETs. *IEEE Access* **2019**, *7*, 56656–56666. doi:10.1109/ACCESS.2019.2913682. [CrossRef]
181. Molina-Masegosa, R.; Gozalvez, J. LTE-V for Sidelink 5G V2X Vehicular Communications: A New 5G Technology for Short-Range Vehicle-to-Everything Communications. *IEEE Veh. Technol. Mag.* **2017**, *12*, 30–39. doi:10.1109/MVT.2017.2752798. [CrossRef]
182. Qiu, H.; Qiu, M.; Lu, Z.; Memmi, G. An efficient key distribution system for data fusion in V2X heterogeneous networks. *Inf. Fusion* **2019**, *50*, 212–220. doi:10.1016/j.inffus.2019.02.002. [CrossRef]
183. Kenney, J.B. Dedicated Short-Range Communications (DSRC) Standards in the United States. *Proc. IEEE* **2011**, *99*, 1162–1182. doi:10.1109/JPROC.2011.2132790. [CrossRef]
184. Vukadinovic, V.; Bakowski, K.; Marsch, P.; Garcia, I.D.; Xu, H.; Sybis, M.; Sroka, P.; Wesolowski, K.; Lister, D.; Thibault, I. 3GPP C-V2X and IEEE 802.11p for Vehicle-to-Vehicle communications in highway platooning scenarios. *Ad Hoc Netw.* **2018**, *74*, 17–29. doi:10.1016/j.adhoc.2018.03.004. [CrossRef]
185. Al-Turjman, F.; Malekloo, A. Smart parking in IoT-enabled cities: A survey. *Sustain. Cities Soc.* **2019**, *49*, 101608. doi:10.1016/j.scs.2019.101608. [CrossRef]
186. Ligo, A.K.; Peha, J.M.; Ferreira, P.; Barros, J. Throughput and Economics of DSRC-Based Internet of Vehicles. *IEEE Access* **2018**, *6*, 7276–7290. doi:10.1109/ACCESS.2017.2785499. [CrossRef]
187. Smith, A. EARN AS YOU DRIVE WITH JAGUAR LAND ROVER AND IOTA. 2019. Available online: https://blog.iota.org/earn-as-you-drive-with-jaguar-land-rover-and-iota-3c744d8c0cba (accessed on 26 January 2020).
188. Carrese, S.; Giacchetti, T.; Patella, S.M.; Petrelli, M. Real time ridesharing: Understanding user behavior and policies impact: Carpooling service case study in Lazio Region, Italy. In Proceedings of the 2017 5th IEEE International Conference on Models and Technologies for Intelligent Transportation Systems (MT-ITS), Naples, Italy, 26–28 June 2017. doi:10.1109/MTITS.2017.8005607. [CrossRef]
189. Santoso, A.S.; Nelloh, L.A.M. User Satisfaction and Intention to Use Peer-to-Peer Online Transportation: A Replication Study. *Procedia Comput. Sci.* **2017**, *124*, 379–387. [CrossRef]
190. Zhu, M.; Liu, X.; Wang, X. An Online Ride-Sharing Path-Planning Strategy for Public Vehicle Systems. *IEEE Trans. Intell. Transp. Syst.* **2019**, *20*, 616–627. doi:10.1109/TITS.2018.2821003. [CrossRef]

191. Tavory, S.S.; Trop, T.; Shiftan, Y. Self-organized ridesharing: Multiperspective annotated review. *Int. J. Sustain. Transp.* **2019**, 1–10. doi:10.1080/15568318.2018.1542758. [CrossRef]
192. Yan, C.Y.; Hu, M.B.; Jiang, R.; Long, J.; Chen, J.Y.; Liu, H.X. Stochastic Ridesharing User Equilibrium in Transport Networks. *Netw. Spat. Econ.* **2019**, *19*, 1007–1030. doi:10.1007/s11067-019-9442-5. [CrossRef]
193. Yu, J.J.Q.; Yu, W.; Gu, J. Online Vehicle Routing With Neural Combinatorial Optimization and Deep Reinforcement Learning. *IEEE Trans. Intell. Transp. Syst.* **2019**, *20*, 3806–3817. doi:10.1109/TITS.2019.2909109. [CrossRef]
194. Teubner, T.; Flath, C.M. The Economics of Multi-Hop Ride Sharing. *Bus. Inf. Syst. Eng.* **2015**, *57*, 311–324. doi:10.1007/s12599-015-0396-y. [CrossRef]
195. Barbosa, H.; Barthelemy, M.; Ghoshal, G.; James, C.R.; Lenormand, M.; Louail, T.; Menezes, R.; Ramasco, J.J.; Simini, F.; Tomasini, M. Human mobility: Models and applications. *Phys. Rep.* **2018**, *734*, 1–74. doi:10.1016/j.physrep.2018.01.001. [CrossRef]
196. Noel, L.; de Rubens, G.Z.; Kester, J.; Sovacool, B.K. Navigating expert skepticism and consumer distrust: Rethinking the barriers to vehicle-to-grid (V2G) in the Nordic region. *Transp. Policy* **2019**, *76*, 67–77. doi:10.1016/j.tranpol.2019.02.002. [CrossRef]
197. Coelho, V.N.; Grasas, A.; Ramalhinho, H.; Coelho, I.M.; Souza, M.J.F.; Cruz, R.C. An ILS-based algorithm to solve a large-scale real heterogeneous fleet VRP with multi-trips and docking constraints. *Eur. J. Oper. Res.* **2016**, *250*, 367–376. doi:10.1016/j.ejor.2015.09.047. [CrossRef]
198. Coelho, I.M.; Munhoz, P.L.A.; Ochi, L.S.; Souza, M.J.F.; Bentes, C.; Farias, R. An integrated CPU–GPU heuristic inspired on variable neighbourhood search for the single vehicle routing problem with deliveries and selective pickups. *Int. J. Prod. Res.* **2016**, *54*, 945–962. doi:10.1080/00207543.2015.1035811. [CrossRef]
199. Silva, M.M.; Subramanian, A.; Ochi, L.S. An iterated local search heuristic for the split delivery vehicle routing problem. *Comput. Oper. Res.* **2015**, *53*, 234–249. doi:10.1016/j.cor.2014.08.005. [CrossRef]
200. Subramanian, A.; Uchoa, E.; Ochi, L.S. A hybrid algorithm for a class of vehicle routing problems. *Comput. Oper. Res.* **2013**, *40*, 2519–2531. doi:10.1016/j.cor.2013.01.013. [CrossRef]

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A multi-criteria view about judicial and legislative decision making in digital cities and societies

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Abstract The constant evolution of cities has driven the development of new tools for society. Applications inspired by operational research techniques, which aid decision-making, can make viable dreams already dreamed up by philosophers. Among these, we highlight more participatory, legitimate and reliable judicial and legislative systems. In this context, a multicriteria analysis seems necessary, balancing the different versions, beliefs, cultures and consequent weights and measures desired by each citizen. In this paper, we present a new model for judicial/legislative processes in digital cities. The system proposes the use of sets of solutions, obtained from different weights adopted according to personal characteristics of those involved in the voting process. From a simple case of study, we highlight the possibilities, flexibility and potential of the proposed system. The proposed framework shows up as promising tool for assisting decision making in other similar voting scenarios.

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1 Introduction

The evolution of cities to a paradigm of decentralized governance has been widely discussed [9]. It is expected that Smart Cities (SC) [1, 20] are going to bring the government closer to citizens [30]. Linked by new information and communication technologies, smart cities drive a strong trend towards decentralized democracies, as mentioned by [24]. Decentralizing decision-making process implies the sharing of decisions, a strategy that has been adopted in technologies inspired by multi-agent systems [8]. In this sense, studies in the field of SC [6, 3] can ensure better and more effective mobility aligned with access to opportunities, especially for urban populations.

In the same way, such systems are emerging as important allies to reach a more independent judiciary [26]. In this context, computational tools, that define adequate limits and weights for different levels of governance, are important resources for more sensible decision making. Initiatives to decentralize governance and promote local participation have been occurring even in rural areas, such as in the village of Panchayats, India [13, 18].

Bi-directional and distributed communication, based on secure, permanent protocols, will undoubtedly be the wisest choice for the cities of the future. In particular, the use of Blockchain based technologies [19, 28] can proportionate trust for those that want to follow this line of reasoning. The Brazilian institute ITS-RIO [15] is currently designing a tool for public petitions by discussing concepts of digital identity focused on the Brazilian scenario. More recently, a notoriously project that focus on digital identities is the one namely The Key [32], developed inside the Ecosystem of the Neo Blockchain [14], formerly Antshares.

Smart devices [25], capable of obtaining information and interacting with the environment, will be an intrinsic part of SC. In this context, applications, models and new paradigms aided by IoT equipment will be a great pillar of modern society [34]. However, reaching conclusions and processing the vast amount of information, extracted and shared in a SC is a task that requires Operational Research (OR), Computational Intelligence (CI) and Optimization knowledge. As mentioned by Gibbard-Satterthwaite [12], every voting rule is subject to manipulation where there are more than two possibilities. The task of computing votes and reaching robust and concrete conclusions has been analyzed as a combinatorial optimization problem [2], of difficult resolution and, in some cases, belonging to the class of NP-Hard problems [16]. There are different possibilities for reaching social agreements through voting, such as plurality with or without elimination, cumulative, approval, peer elimination, among others [27].

In the Brazilian context, reforms in the judiciary have been discussed by the population and by distinct works in the literature [7, 29, 31, 4, 21, 22, 17]. On the other hand, considering the slowness of transformations that require effective changes in laws and old paradigms, we highlight the potential that distributed and encrypted systems have [11]. In this context, we emphasize the role of OR and CI in motivating applications for the emergence of systems and approaches with these

capacities and abilities. As can be expected, more impartial, participatory systems, in which citizens can optionally be anonymous, can become a reality.

In this brief study, we present a computational system, inspired by OR techniques and multi-objective optimization concepts, which could guide the steps towards a more participatory judicial and legislative system. The system described here introduces a weighted voting system. At the end of the process, a set of non-dominated solutions is returned, considering sociodemographic characteristics of those involved in voting. In this system, it is even possible to eliminate alternatives out of context that possible tried to manipulate the system. From a simple case study, we exalt the possibilities, flexibility and power of the proposed methodology, inspired by the use of multicriteria decision-making tools [35]. Such proposal, despite computerizing the system, does not remove the "human" side of the process, it just give strength to the participation of the population in more a transparent and low cost manner. The following contributions of the present work stand out:

- Introduction of a new distributed system in the context of digital cities;
- Design of a voting protocol that is robust against specific sets of weights for socio-demographic information of each individual's profile. It is achieved by generating random weights and presenting results in term of sets of non-dominated solutions.
- Presentation of a multicriteria view to reach relevant facts in a judicial and legislative process;
- Assistance to the decision making process made by judges;
- Motivation of researchers and government officials to invest and develop new technologies for society.
- Alert the population of the current possibilities that are emerging from the insertion of intelligent devices in our daily lives, especially in the context of smart cities.

The remainder of this paper is organized as follows. Section 2 presents the proposed system, as well as the concepts for a framework based on Blockchain concepts (Section 2.3). A case of study, described at Section 3.1, with its results presented at Section 3.2, is considered in order to illustrate a scenario for the application of the proposed tool. Finally, Section 4 concludes this chapter and points out some possible extensions and future work.

2 Decentralized solutions for smart and digital cities

This paper proposes a decentralized and distributed system for judicial processes. A simplified model is described in Section 2.1. The decision-making process, which uses voting data, is described in Section 2.2. It is considered that the data collection and the entire framework is obtained by IoT devices within SCs and the data stored in a Blockchain (as detailed at Section 2.3).

2.1 Proposed system

The interaction of citizens (who can be grouped or self-named in distinct classes) and other social agents can be made by intelligent devices, available in a decentralized way in the context of intelligent cities. Interactive and real-time platforms embedded within these devices, and available to citizens in the region under analysis, will be platforms for data entry/acquisition and dissemination of results. A Blockchain inspired system will be able to store each information of the process in a transparent and permanent way.

A central coordinator, also chosen by similar protocols, could name a set of judges for the case, which would have weights pre-defined by the system. In the current Brazilian system, these jurors can be summoned in cases of intentional crimes against life [5].

After a certain period of survey of the facts, the prosecutor may present his replies as well as new facts. Among these, the system will be able to receive videos, photos, documents and any other digital element. After the period of facts, citizens will have the possibility to vote and give weights for each information/fact of that particular process. In addition, a group of persons may participate jointly, when legally registered with a digital identity. In this same stage, it is emphasized that if there is more than one accused, the process can be divided into several strands with different replicas. On the other hand, a joint model could also be considered, opening the opportunity to access all versions in the same environment.

At any time in the process it will be possible to attach complementary information, even anonymously. The major advantage of integrating these platforms is to ensure a joint information access environment (including data such as those from the 'Ranking of Politicians' portal [23]). Furthermore, it would be possible to easily track trends and felling changes according news and other external influences.

Finally, a decision-making process returns possible facts relevant to the process in question, taking into account different aspects, such as:

- Sociodemographic information of each agent/citizen who participated in the voting;
- Personal data, optionally declared, such as: relative of the victim, witness, among others.

2.2 Multicriteria decision making

This section defines a strategy that can be used to compute each agent's votes (vide [33] for more information on agents and multi-agent systems) involved in the voting process. We describe a decision-making strategy based on weights for each citizen's profile variable, or jury (for cases where necessary); in particular, pre-defined before the process starts. For example, the following set of weights can be defined: 1 ; $1,40$ and 2, respectively, for citizen, victim and jury. In addition, each variable of the

profile of individuals has a specific weight, and it is possible to analyze the impact of certain citizens on the final decision of the voting, for example:

- Three possible income levels with weights $4,2$ and 7, respectively, for low, medium and high incomes. Therefore, the weighted final weight is: $0,31$; $0,15$ and $0,54$.
- Two different education backgrounds, such as with weights 7 and 5;
- Two different gender categories, such as with weights 5 and 5.

Decision making would be done based on the weight for each fact ($n \in [-10,10]$), multiplied by the weight of each involved agent. In this sense, a set of facts and replicas could be $FR = \{(f_1,r_1),(f_2,r_2),\cdots,fr_i,\cdots,(f_z,r_z)\}$ with each individual being able of providing its grade for each set of information fr_i. In this way, the final score of each set would be given by $n^{fr_i} = \sum_{c \in C}(w_c \times n_c^{fr_i})$, being C the effective set of citizens who gave a valid note to the question fr_i. Weights w_c are defined by the weighted average of the weight of each variable considered according to the profile of the individual, ($w_c^v = [0,10]$), where v is one of the analyzed characteristics. In the case of a social group (such as a union or association), the entity could have a specific weight, adopted in view of the number of registered members or a bonus added to the weight of each sitting member who participated in the voting process.

For each grade in an information packet ($n^{fr_i} \mid fr_i \in FR$), positive values would point out facts in favor of the defendant; while, on the other hand, negative values would imply a weighty fact against the accused. In this way, the system would be able to classify the facts that are for and against.

In order to provide a multicriteria analysis, it is proposed to consider different combinations of weights for each sociodemographic variable. Thus, from a set of solutions, it becomes possible to verify the relevant facts for each set of weights, presenting possibilities that vary according to the profile of the people involved in the voting.

2.3 Trust and transparency by using the Blockchain

The information gathering, during all stages of the process, can happen through a reliable, transparent and permanent platform, in which the insertion of new information would be published, permanently, in a Blockchain. Blocks of news, authors, address, files and timestamps tags would be blocked in a transaction and included in a digital registry of the process in question. This tool will enable future analyzes that will relate news and the tendency of the votes on the facts and replicas leveraged in the initial stages (or even during the process).

In addition, by ensuring transparency and security in storing process data (in particular by promoting distributed approaches), future studies may reanalyze the same cases, but with other perspectives.

3 Case of study

The case of study and software developed in the scope of this study can be found at https://github.com/vncoelho/judgmentssmartcities.

3.1 Description of the scenario, facts, cases and motivation

For exemplifying the proposed system, a simple case study was designed, composed of distinct problems generated with random data. There are fictitious scenarios composed from 10 to 110 citizens, 1 to 100 facts and 1 to 30 characteristics analyzed (each with two or three classes). Each possible characteristic of the profile of each involved individual in the voting is also defined in a random fashion.

In order to obtain a set of solutions relevant to the process, composed of different combinations of relevant facts, a large number of combinations of weights were randomly generated. For each characteristic of the profile of those involved in voting, a weight between $1, 10$ is generated for all possible classes (as detailed in Section 2.2). In the experiments described in the next section, 1000 to 10000 random combinations of these weights were analyzed. The total number of experiments performed was 12000. Among these, 2000 experiments were performed to verify the percentage of dominance between solutions with different sets of relevant facts, without considering the order given by the voting weights.

3.2 Obtained results

As can be seen at Figures 1, 2 and 3, the proposed model was able to obtain a large number of non-dominated solutions, defined as relevant. In particular, the method was able to find plenty of non-dominated solutions when the number of facts growth. For these cases, the percentage of non-dominated solutions increases because of the high number of possibilities for generating combinations of relevant facts (as well as different orders of relevance). In this sense, different combinations of weights easily result in different orders of the relevant facts.

Considering this large number of possibilities, it is noteworthy the need for innovative approaches to filter the relevant facts. Among these, the possibility of not considering the order of the relevant facts as a criterion of dominance stands out. Thus, the graph shown in Figure 4 shows that the percentage of non-dominated solutions obtained drops dramatically when order is not considered. In addition, the effects of increased socio-demographic characteristics, Figure 5, appears in a more evident manner.

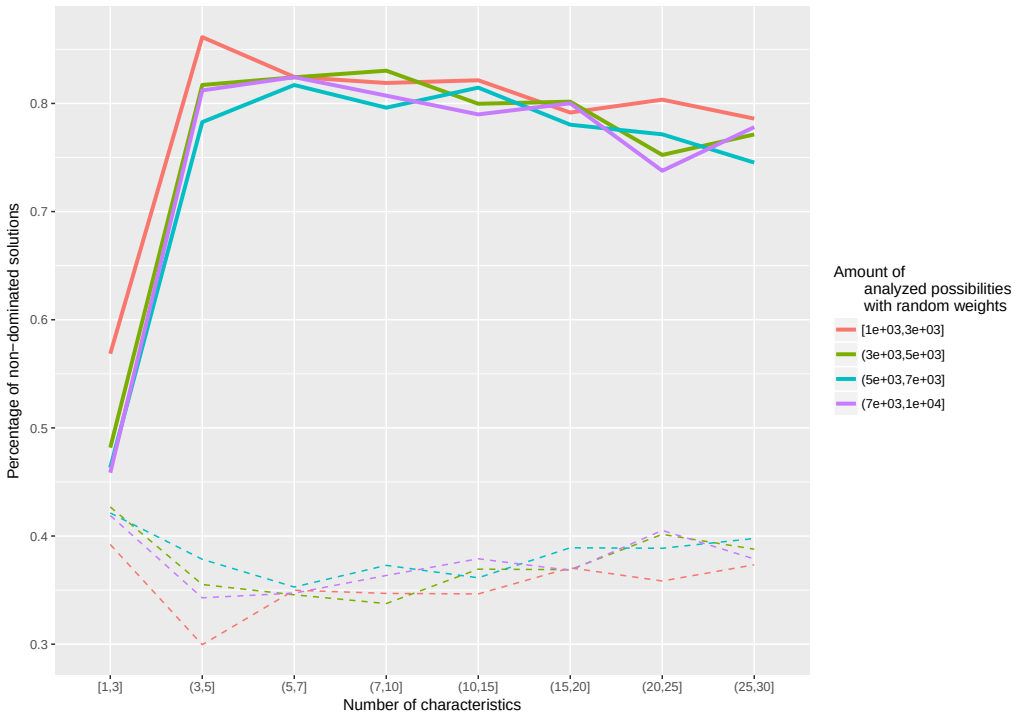

Fig. 1 Interaction graphs between the percentage of solutions obtained, the number of socio-demographic variables and the combinations of weights

4 Final consideration and possible extensions

Considering the constant evolution of cities into distributed paradigms, a new voting system that promotes and analyzes the citizens participation in a digital system was proposed. In particular, the system was developed from a growing need for more balanced judgments and a multicriteria view. The advance and implementation of tools inspired by the strategies introduced here may provide more participatory and "fairer" systems. In view of the current technological advances, it is expected that decentralized and transparent systems will be the core of decision-making in modern/intelligent societies.

The model proposed here could be embedded on several devices already in possession of the citizens or even installed in strategic points of the cities. Future work could consider the influence of external news and data, connecting publication and disclosure of this information against voting trends (during the period the process is open).

An additional step in the process could consider the exclusion of all those who facts with final weight ≥ 0, since these facts are in favor of the defendant or have no

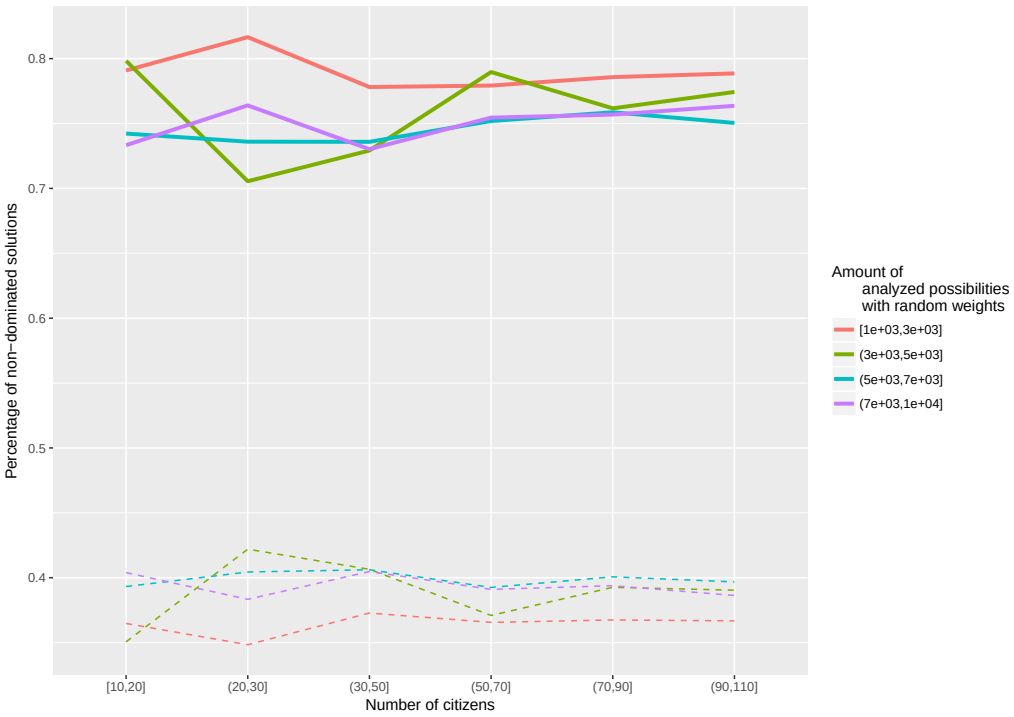

Fig. 2 Relationship between the percentage of non-dominated solutions and the number of citizens involved in the voting process

relevance (such facts may also have received these notes because they are possibly manipulated facts). Finding specific weights that give rise to certain conclusions is another strategy that could be adopted to understand the wishes of those involved in voting. Therefore, metaheuristic algorithms could seek solutions that increase and optimize the set of non-dominated solutions, expanding the range and power of possible conclusions.

As a future possibility, the use of classical decision-making techniques such as PROMETHEE II and Analytic Hierarchy Process (AHP) [10] is recommended, which are usually used to find satisfactory alternatives among possible solutions. In this sense, one could consider the weights already provided by those involved in the voting and forward them to the AHP technique for defining the most relevant points of the process.

The proposal of this work motivates the advancement of novel voting protocols, not only for the challenging problems of our cities, but also for the scope of novel negotiation protocols for multi-agent systems. The idea of bringing the evolution of computational techniques closer to the devices used by citizens, with a focus on impartiality and transparency, could possible impact on significant advances in the quality of life of future societies.

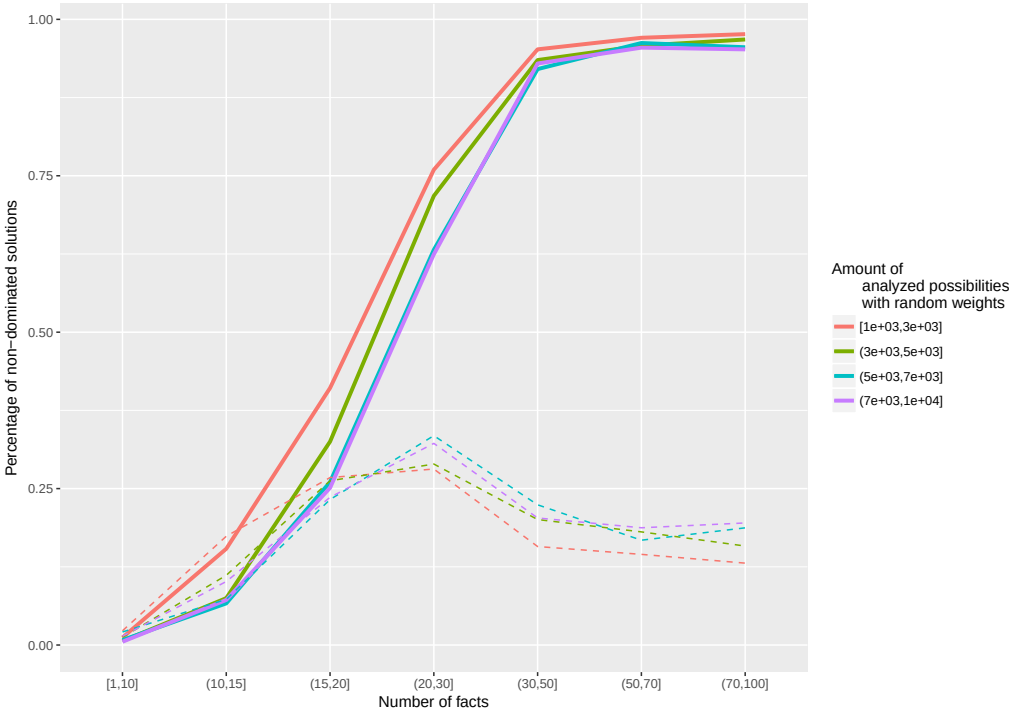

Fig. 3 Growth on the rate of non-dominated solutions with the increase in the number of considered facts

References

1. Almirall, E., Wareham, J., Ratti, C., Conesa, P., Bria, F., Gaviria, A., Edmondson, A.: Smart cities at the crossroads: New tensions in city transformation. California Management Review **59**(1), 141–152 (2016)
2. Bartholdi III, J.J., Tovey, C.A., Trick, M.A.: The computational difficulty of manipulating an election. Social Choice and Welfare **6**(3), 227–241 (1989)
3. Batty, M., Axhausen, K.W., Giannotti, F., Pozdnoukhov, A., Bazzani, A., Wachowicz, M., Ouzounis, G., Portugali, Y.: Smart cities of the future. The European Physical Journal Special Topics **214**(1), 481–518 (2012). DOI 10.1140/epjst/e2012-01703-3
4. Brinks, D.: Judicial reform and independence in brazil and argentina: the beginning of a new millennium. Tex. Int'l LJ **40**, 595 (2004)
5. Cady, M.C., Yin, C.W., de Araújo Filho, J.P., Vasconcelos, A., Nascimento, J.M.B., de Jesus Cerqueira, A., Olívia, M., Setúbal, S., Junior, O.P.S., Pessoa, R.B.: Tribunal do júri: uma breve reflexão. Jus Navigandi. Teresina. a **9** (2014)
6. Cano, J., Hernandez, R., Ros, S.: Distributed framework for electronic democracy in smart cities. Computer **47**(10), 65–71 (2014)
7. Carvalho, E., Leito, N.: The power of judges: The supreme court and the institutional design of the national council of justice [o poder dos juzes: Supremo tribunal federal e o desenho institucional do conselho nacional de justia]. Revista de Sociologia e Politica **21**(45), 13–27 (2013). DOI 10.1590/S0104-44782013000100003

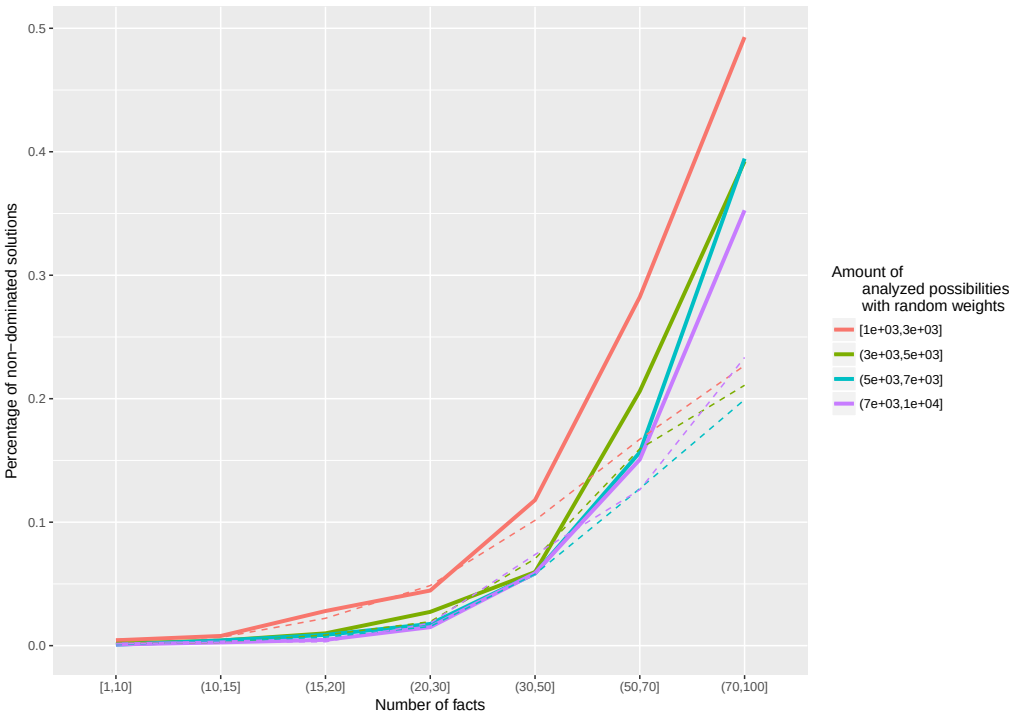

Fig. 4 Growth on the number of non-dominated solutions with the increase in the number of considered facts, considering only dominant solutions with different relevant facts

8. Chalkiadakis, G., Elkind, E., Polukarov, M., Jennings, N.R.: The price of democracy in coalition formation. In: Proceedings of The 8th International Conference on Autonomous Agents and Multiagent Systems - Volume 1, AAMAS '09, pp. 401–408. International Foundation for Autonomous Agents and Multiagent Systems, Richland, SC (2009). URL http://dl.acm.org/citation.cfm?id=1558013.1558068
9. Coe, A., Paquet, G., Roy, J.: E-governance and smart communities: a social learning challenge. Social science computer review **19**(1), 80–93 (2001)
10. Dağdeviren, M.: Decision making in equipment selection: an integrated approach with ahp and promethee. Journal of Intelligent Manufacturing **19**(4), 397–406 (2008)
11. Dai, W.: b-money (1998). URL http://www.weidai.com/bmoney.txt
12. Endriss, U.: Vote manipulation in the presence of multiple sincere ballots. In: Proceedings of the 11th conference on Theoretical aspects of rationality and knowledge, pp. 125–134. ACM (2007)
13. Gokhale, S., Kapshe, C.: Review of decentralised planning initiatives and urban local government functions in india. Dynamics of Local Governments: A Comparative Study of India, UK and the USA pp. 85–Local Government Quarterly (2016)
14. Hongfei, Da and Zhang, Erik: Neo: A distributed network for the smart economy (2018). URL https://github.com/neo-project/docs/blob/master/en-us/whitepaper.md
15. Lemos, R.: Using the blockchain for the public interest (2016). URL https://medium.com/positive-returns/using-the-blockchain-for-the-public-interest-2ed1f5114036

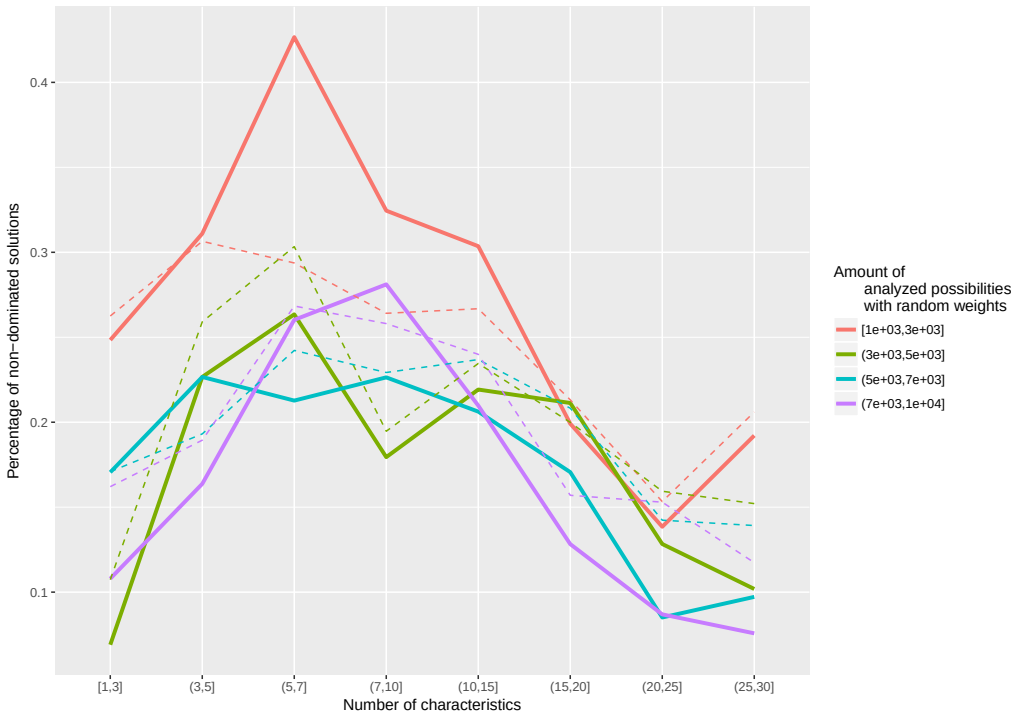

Fig. 5 Increase in the number of variables per individual and impact on the percentage of non-dominated solutions

16. Mattei, N., Narodytska, N., Walsh, T.: How hard is it to control an election by breaking ties? arXiv preprint arXiv:1304.6174 (2013)
17. Melo Filho, H.C.: A reforma do poder judiciário brasileiro. In: Seminário sobre a Reforma do Judiciário (2003)
18. Mission, S.C.: Ministry of urban development, government of india (2015) (2015). URL http://smartcities.gov.in/content/innerpage/strategy.php
19. Nakamoto, S.: Bitcoin: A peer-to-peer electronic cash system (2008)
20. Odendaal, N.: Towards the digital city in south africa: Issues and constraints. Journal of Urban Technology **13**(3), 29–48 (2006)
21. Pinheiro, A.C.: A reforma do judiciário: uma análise econômica. Trabalho apresentado no Seminário Internacional "Sociedade e a Reforma do Estado", realizado em São Paulo de **26** (1998)
22. Pinheiro, A.C.: Judiciário, reforma e economia: a visão dos magistrados. Instituto de Pesquisa Econômica Aplicada (Ipea) (2003). URL http://hdl.handle.net/11058/2900
23. Políticos, R.: Ranking políticos (2014). URL http://www.politicos.org.br/
24. Roberts, N.: Public deliberation in an age of direct citizen participation. The American review of public administration **34**(4), 315–353 (2004)
25. Schaffers, H., Komninos, N., Pallot, M., Trousse, B., Nilsson, M., Oliveira, A.: Smart cities and the future internet: Towards cooperation frameworks for open innovation. In: The Future Internet Assembly, pp. 431–446. Springer (2011)
26. Shah, A.: Balance, accountability, and responsiveness: lessons about decentralization. World Bank Policy Research Working (2021) (1999). URL https://ssrn.com/abstract=623937

27. Shoham, Y., Leyton-Brown, K.: Multiagent systems: Algorithmic, game-theoretic, and logical foundations, chap. Aggregating Preferences: Social Choice. Cambridge University Press (2008)
28. Silva, L.: Smartcities on the ethereum blockchain (2016). URL https://www.ethnews.com/the-future-is-now-smart-cities-on-the-ethereum-blockchain
29. Sinhoretto, J.: Law reform (case study) [reforma da justia (estudo de caso)]. Tempo Social **19**(2), 157–177 (2007)
30. Stepan, A.: Brazil's decentralized federalism: Bringing government closer to the citizens? Daedalus **129**(2), 145–169 (2000)
31. Terra, L., Ventura, C., Medeiros, M., Passador, J.: Strategies for the distribution of power in brazil: A proposal from the perspective of the viable system model (VSM). Systems Research and Behavioral Science **33**(2), 224–234 (2016). DOI 10.1002/sres.2378
32. The Key: Thekey: A decentralized ecosystem of an identity verification tool using national big-data and blockchain (2017)
33. Weyns, D., Omicini, A., Odell, J.: Environment as a first class abstraction in multiagent systems. Autonomous Agents and Multi-Agent Systems **14**(1), 5–30 (2007). DOI 10.1007/s10458-006-0012-0
34. Zanella, A., Bui, N., Castellani, A., Vangelista, L., Zorzi, M.: Internet of things for smart cities. IEEE Internet of Things journal **1**(1), 22–32 (2014)
35. Zeleny, M., Cochrane, J.L.: Multiple criteria decision making. University of South Carolina Press (1973)

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When CI and decentralized systems effectively meet smart cities and grids

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Abstract A global trend has been motivating programmers, investors and the academia to go towards decentralized systems. Besides providing efficient solutions for complex problems faced in our daily life, these peer-to-peer communication protocols have been promoting greater freedom and transparency. In this paper, we point out open fields for researching, thinking and developing in the context of Smart Cities and Smart Grids. Future cities will surely rely on efficient, autonomous, transparent, collaborative and decentralized environment. In particular, we consider how renewable energy resources could be integrated with mini/microgrids, which will be hearth of the future cities. Furthermore, we discuss possibilities for promoting territorial development, through the assistance of Blockchain based platforms embedded with Computational Intelligence tools.

1 Introduction

Academia and the industry are moving towards decentralization and scalable approaches for handling our modern systems [48]. Several decentralization levels ex-

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ist in order to achieve specific goals, such as providing greater service stability and allowing the emergence of more scalable solutions to deal with computationally expensive problems. Public databases and lots of papers are now being stored into public decentralized storages, including ledgers [35]. Recent groundbreaking technological advances managed to solve the double-spending problem, creating the first public distributed ledger, called the Blockchain, supporting Bitcoin cryptocurrency [39]. Many other blockchain technologies have been developed since then, inspired by the success improvements on the open-source code of projects like: Ethereum [12], Neo, Ripple, Litecoin, among others. The integration of blockchain technology with smart contract languages, such as Solidity [53], allowed the creation of trustless computing networks that are fully autonomous and capable of replacing centralized infrastructures. The case of Brooklyn Microgrid (BMG) [37] is an interesting recent example of connection between Smart Grids and Blockchain based technologies [25]. Figure 1, inspired from [37], exemplifies the virtual and physical layers of BMG, which will intrinsically be the heart of distributed power trading. This combination of fully distributed components with high-performance computing is also going to be part of cities' environment. As can be seen, deterministic and reliable engines should take care of market operations, while private blockchains can play the role of the and transparency and reliability.

Discussions surrounding what are the Smart Cities (SC) [44] have been recently reaching several strategical areas. In particular, works from the literature have been highlighting the importance of the energy grid in these idealized cities [33]. As pointed out by Hofman et al [29], better energy quality may even leads to greater availability of high quality fresh water. Renewable energy resources may even pro-

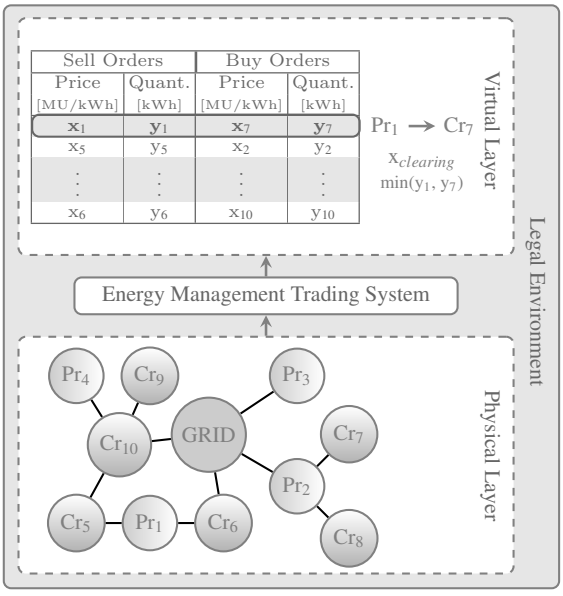

Fig. 1 Schematic example of physical and virtual layers of a microgrid

mote remigration to rural areas, as well as preventing urban exodus [30], due to the possibility of offering "urban services and facilities" in isolated spots and promoting smart territories.

In addition, with the rise of these aforementioned distributed databases, in connection with with peer-to-peer cash systems [39], can change the way SC will interact with citizens and devices [45]. The idea of establish and transform communities for using these systems can turn some points emphasized by Wei Dai in 1998 into reality, reproduced below [20]:

> "I am fascinated by Tim May's crypto-anarchy. Unlike the communities traditionally associated with the word "anarchy", in a crypto-anarchy the government is not temporarily destroyed but permanently forbidden and permanently unnecessary. It's a community where the threat of violence is impotent because violence is impossible, and violence is impossible because its participants cannot be linked to their true names or physical locations.
>
> Until now it's not clear, even theoretically, how such a community could operate. A community is defined by the cooperation of its participants, and efficient cooperation requires a medium of exchange (money) and a way to enforce contracts. Traditionally these services have been provided by the government or government sponsored institutions and only to legal entities. (...)"

In this paper, we contribute to the literature by discussing the importance of evolving the energy grids and how decentralized technologies can promote a stable and fair system, throughout the use of Computational Intelligence (CI) tools, in connection with the future cities. Through an interdisciplinary perspective, we highlight citizens possibilities and their important role in this transformation in order to promote the balance between the efficiency and resilience of sociotechnical systems.

This paper is organized in five sections, including this Introduction. Section 2 describes the state-of-the-art for energy systems in fully distributed environments and smart cities, also pointing out current challenges. Section 3 discuss the impact of decentralization for urban and rural areas, and how smart grids and decentralized systems are reshaping society organization. Section 4 presents open challenges and how they can be possibly solved by applying distributed technologies combined with computational intelligence. Finally, Section 5 concludes the work, with a brief discussion and future perspectives on the topic of smart cities, computational intelligence and distributed systems.

2 Current challenges and state-of-the-art systems

The concept of decentralization is commonly referred to any activity that used to be centralized, both in terms of private businesses or the government policies, for instance. An example with supply chain case can help us clarify the change that has happened. Firstly, the distribution center used to be centralized for better control and supervision of the whole process, but it used to have a big lack on velocity and high delivery cost. So, some improvements were made to adjust those two variables such

as inserting other distribution centers on strategic places to deal with all related demands. The constant evolution of distributed distribution centers has been improved by Artificial Intelligence (AI) and CI data analysis, being the measure of its impact the success by customers satisfaction, a real market thermometer. Self-adaptive systems have gained much improved learning capabilities even for complex problems, such as AlphaGo, that performed the near impossible task of beating the world champion of Go [46].

Similarly, expansion on power grids was shaped by consumers needs, distinguishing by the way studies and planning were conducted though. On electricity market, stakeholders used to be divided in groups accordingly with similar technical characteristics and this is considered to determine future power demand and generation, based simply on linear growth planning [22]. On supply chain case, stakeholders have a more important role since their inputs are considered to determine the best solution for each occasion, given to its future plan operation a dynamism and complex behavior.

In our society, it is broadly accepted the importance of electricity in any activity. Not just for country economic growth/stability but as well for a rising on humanity quality of life [31]. In this way, decentralization of power generation and redesign of energy market sounds trivial, if not for difficulty in integration of small power customers into metering data sharing and technical issues [32].

Solar cells are becoming more affordable and, consequently, deployment of residential photovoltaic microgrids is increasing [28, 47]. Furthermore, optimization and novel simulation tools are assisting the achievement of efficient and resilient solar cells [27]. Coelho *et al.*[17] pointed out possibilities for using electric vehicles in connection with citizens wishes, designing a novel optimization model for planning energy power dispatching in a multi-criteria view. On the other hand , a centralized agent can not handle this scenario in an effective manner. Not only because it would be subjected to optimize its own profits, but also because high costly computational activities are requested. In this sense, a fully distributed systems sounds reasonable. On the other hand, these system require smart devices to interact and reach agreements, as highlighted by Coelho *et al.*[19]. MAS paradigms are an interesting and groundbreaking solutions for mini/microgrid and smart cities' services that relies on autonomous agents.

The mini/microgrid concept is part of this change, in which Distributed Energy Resources (DER) have been gradually implemented, promoting traditional power grids in regard to local electricity needs and desire [7]. Different cases around the world have been facing several technical challenges and resolutions [23]. Either for differences in power access on urban and rural areas or in levels of power capacity installed.

Despite technical subjects, however, some approaches are arising to connect people directly and reshape the way energy market behave by optimizing territorial supply and demand. Although mini/microgrid communities with DER act off-grid as an outcome to the lack of power lines in rural areas [31], the communication between its adopters used to be *in locu* and defined as a one-way-direction problem solving. In addition, these systems have been used by citizens to generate green energy lo-

cally on the existing power network. Moreover, blockchain technology is allowing a broadly opportunity for those groups to exchange electricity as a custom business model instead.

Decentralization is a well known term on computer environment. Computer technologies and architectures have been a "trend of fluctuation between the centralization and subsequent decentralization of computing power, storage, infrastructure, protocols, and code" [24]. Blockchain, in its turn, are impacting directly on how computing, storage, and processing are used relying on "a peer-to-peer distributed ledger forged by consensus, combined with a system for 'smart contracts' and other assistive technologies" [24]. In which it "give(s) explicit control of digital assets to end-users and remove the need to trust any third-party servers and infrastructure" [10].

On this scope, individuals have been experiencing a diverse return beyond the usual (and expected) profit. For instance, it is already possible to send power credits via cryptocurrency payment to a remote intercontinental smart meter for a limited energy consuming period, working as a prepaid power bill plan, and a way to charity safely [3]. Additionally, it is relevant to point out that sustainable development is territorially embedded and in an anthropological way it is about enhancing individual competences and autonomy [41]. Therefore, DER can promote social innovations by empowering local rural users to become solar entrepreneurs, to deal with solar power as an investment program, to connect households and businesses in a diverse approach [2]. Through the same approach, although under a limited group in a big city, the raised flag is both sustainability and independence. Either in order to choose a preferred power source or to stay powered on during a blackout [1]. In a more broad spectrum of initiatives, by partnering with local power utility, individuals take part to be co-creators and co-responsible for their energy needs and supply, no matter where you are from, because blockchain tokens can be acquired by anyone in the world, i.e. individuals can be a nature activist, a local grid user or a remote investor. Within this environment all views commented before are possible and new ones keep welcome too [4]. With this regards, it is important to highlight the issue of governance of distributed ledger technologies [16, 51]. Crossing out borders, the same project has aided to create the term Microgrid-as-a-Service (MaaS), where the generation and management of each individual electricity open space to trade it in case of excess energy [5].

The development of these new approaches have been improving solutions and creating new local challenges, specifically on cities, where social, economical and political structures are tighter. Nevertheless, it is only on the embryonic stage, what may explain a certain enthusiasm.

3 Connecting individuals and services in urban and rural areas

Smart cities should be designed and receive a special attention in handling decentralized energy sources. Policy-makers should be aware about the possibilities

and the role of decentralizing infrastructure. Therefore, think tanks and territorial technology centers implementation are of extreme importance. These establishments are the geographical representation of the bridge for interdisciplinary applied research. Several countries around the globe are embarking on this journey [21, 49, 9, 40, 34, 6, 52, 13]. A question that has been bordering the energy planner is: "Will an adapted energy grid become better than a new designed one, coming from the sand?" Several novel start-ups are being developed in countries in the "Global South", motivating studies and innovation on these cities under development.

Energy commercialization is in the heart of the future cities, allowing more efficient, reliable and cheaper energy. It is relevant to point out the great potential for this distributed energy exchange scenarios. It may enact the sharing economy development and territorial cohesion being interpreted by society as an exchange agreement. By localizing this supply and demand challenges the process of resilience-building is much more likely to happen. The idea of using a blockchain-based software for peer-to-peer energy trading has been quoted in Australia [50], tracking energy trade from point to point.

Citizens houses and buildings will respond to price signals from the market and interact with the energy grid [38]. Demand Response has been advocated as a new Virtual Energy Storage System (VESS), able to intelligently manage energy consumption of loads [14]. Large amount of available data will surely assist this aforementioned tasks [11].

To guarantee the shared control of these DER, by who is being directly benefited from it, a set of rules and guidelines must be clearly defined in advance. Only by doing so we can indeed promote a smart and decentralized governance systems in terms of urban/territorial collaboration [36]. This structure can be supported, for example, by the Ethereum-based Decentralized Autonomous Organizations (DAO). This tool can enable the participation of the stakeholders, consolidate a transparent voting system and solve conflicts without the need of high levels of human capital [15].

4 Open Challenges and future research directions

Renewables penetration as mini/microgrid will surely affect power system reliability, because power grid operation used to be stable with synchronous machines correlation between generation and consuming balances, and now and beyond this pattern will be more discrete [7]. All variables that imply on power quality will demand particular attention to keep on acceptable levels. Studies of the effect of distributed energy has already been discussing to surpass those challenges [32]. Specifically, those concerning load forecasting [22][18] and economics behavior compared to energy balance with DER and electricity storage [17, 54].

Even though DER have a positive return for its adopters and blockchain could expand these enthusiasm, "the success, failure and reasons behind its adoption can

stem from a multitude of different policies that are often strongly rooted in the individual context of each country" [42]. Ramalho *et al.*[42] complement that "decentralized and socialized provision of energy will clear the path for an aspired participatory form of democracy", but financial and economical crises have a huge influence on policy motivation and adoption to support it. As an example, for some utilities' business model, current rate structure is inadequate for dealing with such diffusion, creating cross subsidies and threatening the important economic equilibrium of the power services [26].

Moreover,the smartness expected for the city of the future is open to develop not only power grid innovation, but social aspects as well. In this sense, architecture, social geography, regional and urban planning are the main disciplines related to understand the incoherent performance of cities, crafted by its own citizens [43] in a run to urban areas. Therefore, experts from these field can contribute to better comprehension of negative gentrification processes. That is, consequences that can lead to population migration and displacement forced by community restructuring or law imposing [8]. CI abilities should bare this issue in mind.

5 Final considerations

We have discussed in this paper topics involving decentralized systems (mainly smart grids) and their impact on society. Based on dozens of references in literature, we strongly believe that support fully distributed paradigms is the key behind several recent groundbreaking technologies (including cryptocurrencies and blockchain), becoming a necessary tool for society transformation. These systems can provide secure infrastructure with redundant information and high service availability, also becoming a path for freedom and transparency. The transparency is a fundamental feature of Smart Cities, in order to empower citizens with real-time information and capability to take informed decisions that avoid corruption.

One industry that will suffer greater impact in the following years is the energy sector. Smart grids are already being implemented to connect small customers (even in Brazil after recent regulation changes). For instance, neighbors in Brooklyn already have the capability to exchange energy. Renewable energy (mainly solar) is now attracting the interest of small customers, which in turn are demanding a stronger participation in the free markets (although some third-party blockchain technologies are already allowing such exchanges), creating larger grids with local generators/prosumers. Although it is not possible to know in advance which technologies will become "standards" for Smart Cities in a near future, it is inevitable to realize that many of these changes are coming to stay. Therefore, the next steps to me taken will shape society considerably and the precautionary principle guide them. More now than never, everyone is responsible for technology use and development.

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References

1. Brooklyn microgrid project - lo3 energy. URL https://www.brooklyn.energy/
2. Solshare. URL https://www.me-solshare.com/
3. (2016). URL http://www.mitforumcambridge.org/event/the-blockchain-enabling-a-distributed-and-connected-energy-future/. The Blockchain: Enabling a Distributed & Connected Energy Future
4. (2017). URL https://powerledger.io/media/Power-Ledger-Whitepaper-v3.pdf. Power Ledger Whitepaper
5. (2017). URL https://www.techmahindra.com/media/press_releases/TechMahindra-PowerLedger-unite-to-unleash-the-powerofMaaS.aspx. Tech Mahindra and Power Ledger unite to unleash the power of MaaS
6. Acharjee, P.: Strategy and implementation of smart grids in india. Energy Strategy Reviews **1**(3), 193 – 204 (2013). DOI http://dx.doi.org/10.1016/j.esr.2012.05.003. Future Energy Systems and Market Integration of Wind Power
7. Ackermann, T., Prevost, T., Vittal, V., Roscoe, A.J., Matevosyan, J., Miller, N.: Paving the way. IEEE Power & Energy Magazine **15**(6), 61 – 69 (2017). DOI 10.1109/MPE.2017.2729138. November/December
8. Albright, C.: Gentrification is sweeping through america. here are the people fighting back (2017). URL https://www.theguardian.com/us-news/2017/nov/10/atlanta-super-gentrification-eminent-domain
9. Alemán-Nava, G.S., Casiano-Flores, V.H., Cárdenas-Chvez, D.L., Díaz-Chavez, R., Scarlat, N., Mahlknecht, J., Dallemand, J.F., Parra, R.: Renewable energy research progress in mexico: A review. Renewable and Sustainable Energy Reviews **32**(0), 140 – 153 (2014). DOI http://dx.doi.org/10.1016/j.rser.2014.01.004
10. Ali, M.: The next wave of computing (2017). URL https://medium.com/@muneeb/the-next-wave-of-computing-743295b4bc73
11. Batty, M.: Big data, smart cities and city planning. Dialogues in Human Geography **3**(3), 274–279 (2013)
12. Buterin, V.: Ethereum white paper: A next generation smart contract & decentralized application platform (2013). URL http://www.the-blockchain.com/docs/Ethereum_white_paper-a_next_generation_smart_contract_and_decentralized_application_platform-vitalik-buterin.pdf
13. Chen, Y.H., Lu, S.Y., Chang, Y.R., Lee, T.T., Hu, M.C.: Economic analysis and optimal energy management models for microgrid systems: A case study in taiwan. Applied Energy **103**(0), 145 – 154 (2013). DOI http://dx.doi.org/10.1016/j.apenergy.2012.09.023
14. Cheng, M., Sami, S.S., Wu, J.: Benefits of using virtual energy storage system for power system frequency response. Applied Energy (2016). DOI http://dx.doi.org/10.1016/j.apenergy.2016.06.113
15. Chohan, U.: The decentralized autonomous organsations and governance issues. SSRN Electronic Journal (2017). DOI 10.2139/ssrn.3082055
16. Christidis, K., Devetsikiotis, M.: Blockchains and smart contracts for the internet of things. IEEE Access **4**, 2292–2303 (2016)
17. Coelho, V.N., Coelho, I.M., Coelho, B.N., de Oliveira, G.C., Barbosa, A.C., Pereira, L., de Freitas, A., Santos, H.G., Ochi, L.S., Guimarães, F.G.: A communitarian microgrid stor-

age planning system inside the scope of a smart city. Applied Energy pp. – (2016). DOI http://dx.doi.org/10.1016/j.apenergy.2016.12.043. Final publication expected to 2017.
18. Coelho, V.N., Coelho, I.M., Rios, E., Filho, A.S.T., Reis, A.J.R., Coelho, B.N., Alves, A., Netto, G.G., Souza, M.J., Guimaraes, F.G.: A hybrid deep learning forecasting model using gpu disaggregated function evaluations applied for household electricity demand forecasting. Energy Procedia **0**, 1 – 6 (2016). To appear
19. Coelho, V.N., Cohen, M.W., Coelho, I.M., Liu, N., Guimarães, F.G.: Multi-agent systems applied for energy systems integration: State-of-the-art applications and trends in microgrids. Applied Energy **187**, 820 – 832 (2017). DOI http://dx.doi.org/10.1016/j.apenergy.2016.10.056
20. Dai, W.: b-money (1998). URL http://www.weidai.com/bmoney.txt
21. Díaz, P., Masó, J.: Evolution of production and the efficient location of renewable energies. the case of china. Energy Procedia **40**(0), 15 – 24 (2013). DOI http://dx.doi.org/10.1016/j.egypro.2013.08.003. European Geosciences Union General Assembly
22. Dobschinski, J., Bessa, R., Du, P., Geisler, K., Haupt, S.E., Lange, M., Mhrlen, C., Nakafuji, D., de la Torre Rodriguez, M.: Uncertainty forecasting in a nutshell. IEEE Power & Energy Magazine **15**(6), 40 – 49 (2017). DOI 10.1109/MPE.2017.2729100. November/December
23. Ela, E., Wang, C., Moorty, S., Ragsdale, K., O'Sullivan, J., Rothleder, M., Hobbs, B.: Electricity markets and renewables. IEEE Power & Energy Magazine **15**(6), 70 – 82 (2017). DOI 10.1109/MPE.2017.2730827. November/December
24. Foundation, T.L.: Blockchain for business - an introduction to hyperledger technologies (2017). URL https://www.edx.org/course/blockchain-business-introduction-linuxfoundationx-lfs171x. EdX MOOC
25. Gabrich, Y.B., Coelho, I.M., Coelho, V.N.: Tendências para sistemas microgrids em cidades inteligentes: Uma visão sobre a blockchain. In: XLIX Simpsio Brasileiro de Pesquisa Operacional, pp. 1 – 12. Blumenau, SC (2017)
26. Gianelloni, F., de Azevedo Dantas, G., Alves, J.F., de Castro, N.: The distributed electricity generation diffusion impact on the brazilian distribution utilities. 3rd International Conference on Energy and Environment: bringing together Engineering and Economics (2017). URL https://goo.gl/5bmqU3. Porto, Portugal
27. Green, M.A., Hishikawa, Y., Warta, W., Dunlop, E.D., Levi, D.H., Hohl-Ebinger, J., Ho-Baillie, A.W.: Solar cell efficiency tables (version 50). Progress in Photovoltaics: Research and Applications **25**(7), 668–676 (2017). DOI 10.1002/pip.2909. PIP-17-089
28. Hameiri, Z.: Photovoltaics literature survey (no. 138). Progress in Photovoltaics: Research and Applications **25**(12), 1077–1083 (2017). DOI 10.1002/pip.2967
29. Hofman, J., Hofman-Caris, R., Nederlof, M., Frijns, J., Van Loosdrecht, M.: Water and energy as inseparable twins for sustainable solutions. Water Science and Technology **63**(1), 88–92 (2011)
30. Horio, M., Shigeto, S., Ii, R., Shimatani, Y., Hidaka, M.: Potential of the renewable energy exodus (a mass rural remigration) for massive {GHG} reduction in japan. Applied Energy **160**, 623 – 632 (2015). DOI http://dx.doi.org/10.1016/j.apenergy.2015.03.087
31. IEA, I.E.A.: Energy access outlook 2017, from poverty to prosperity (2017). URL https://www.iea.org/publications/freepublications/publication/weo-2017-special-report-energy-access-outlook.html
32. Lew, D., Asano, M., Boemer, J., Ching, C., Focken, U., Hydzik, R., Lange, M., Motley, A.: The power of small. IEEE Power & Energy Magazine **15**(6), 50 – 60 (2017). DOI 10.1109/MPE.2017.2729104. November/December
33. Li, M., Xiao, H., Gao, W., Li, L.: Smart grid supports the future intelligent city development. In: 2016 Chinese Control and Decision Conference (CCDC), pp. 6128–6131 (2016). DOI 10.1109/CCDC.2016.7532097
34. Lin, C.C., Yang, C.H., Shyua, J.Z.: A comparison of innovation policy in the smart grid industry across the pacific: China and the {USA}. Energy Policy **57**(0), 119 – 132 (2013). DOI http://dx.doi.org/10.1016/j.enpol.2012.12.028

35. Mainelli, M., Smith, M., et al.: Sharing ledgers for sharing economies: an exploration of mutual distributed ledgers (aka blockchain technology). The Journal of Financial Perspectives **3**(3), 38–69 (2015)
36. Meijer, A.J., Gil-Garcia, J.R., Bolvar, M.P.R.: Smart city research: Contextual conditions, governance models, and public value assessment. Social Science Computer Review **34**(6), 647–656 (2016). DOI 10.1177/0894439315618890. URL https://doi.org/10.1177/0894439315618890
37. Mengelkamp, E., Grttner, J., Rock, K., Kessler, S., Orsini, L., Weinhardt, C.: Designing microgrid energy markets: A case study: The brooklyn microgrid. Applied Energy **210**, 870 – 880 (2018). DOI https://doi.org/10.1016/j.apenergy.2017.06.054
38. Morvaj, B., Lugaric, L., Krajcar, S.: Demonstrating smart buildings and smart grid features in a smart energy city. In: Energetics (IYCE), Proceedings of the 2011 3rd International Youth Conference on, pp. 1–8. IEEE (2011)
39. Nakamoto, S.: Bitcoin: A peer-to-peer electronic cash system (2008)
40. Pao, H.T., Fu, H.C.: Renewable energy, non-renewable energy and economic growth in brazil. Renewable and Sustainable Energy Reviews **25**(0), 381 – 392 (2013). DOI http://dx.doi.org/10.1016/j.rser.2013.05.004
41. Pike, A., Rodrguez-Pose, A., Tomaney, J.: What kind of local and regional development and for whom? Regional Studies **41**(9), 1253–1269 (2007). DOI 10.1080/00343400701543355
42. Ramalho, M.S., Cmara, L., Slva, P.P., Pereira, G., Dantas, G.: Assessing energy policies drivers of the deployment of distribution generation: A review of influencing factors. 3rd International Conference on Energy and Environment: bringing together Engineering and Economics (2017). URL https://goo.gl/EaLzYs. Porto, Portugal
43. Sennett, R.: The open city. URL https://goo.gl/m2u85a
44. Shetty, V.: A tale of smart cities. Communications International (London) **24**(8), 16 (1997)
45. Silva, L.: Smartcities on the ethereum blockchain (2016). URL https://www.ethnews.com/the-future-is-now-smart-cities-on-the-ethereum-blockchain
46. Silver, D., Huang, A., Maddison, C.J., Guez, A., Sifre, L., van den Driessche, G., Schrittwieser, J., Antonoglou, I., Panneershelvam, V., Lanctot, M., Dieleman, S., Grewe, D., Nham, J., Kalchbrenner, N., Sutskever, I., Lillicrap, T., Leach, M., Kavukcuoglu, K., Graepel, T., Hassabis, D.: Mastering the game of go with deep neural networks and tree search. Nature **529**, 484–489 (2016). DOI 10.1038/nature16961
47. Swaleh, M., Green, M.: Effect of shunt resistance and bypass diodes on the shadow tolerance of solar cell modules. Solar Cells **5**(2), 183 – 198 (1982). DOI https://doi.org/10.1016/0379-6787(82)90026-6. URL http://www.sciencedirect.com/science/article/pii/0379678782900266
48. Swan, M.: Blockchain: Blueprint for a new economy. " O'Reilly Media, Inc." (2015)
49. Tugcu, C.T., Ozturk, I., Aslan, A.: Renewable and non-renewable energy consumption and economic growth relationship revisited: Evidence from G7 countries. Energy Economics **34**(6), 1942 – 1950 (2012). DOI http://dx.doi.org/10.1016/j.eneco.2012.08.021
50. Vorrath, S.: Bitcoin-inspired peer-to-peer solar trading trial kicks off in perth : Renew economy. http://reneweconomy.com.au/bitcoin-inspired-peer-to-peer-solar-trading-trial-kicks-off-in-perth-29362/. (Accessed on 02/17/2017)
51. Walport, M.: Distributed ledger technology: Beyond blockchain. UK Government Office for Science (2016)
52. Welsch, M., Bazilian, M., Howells, M., Divan, D., Elzinga, D., Strbac, G., Jones, L., Keane, A., Gielen, D., Balijepalli, V.M., Brew-Hammond, A., Yumkella, K.: Smart and just grids for sub-saharan africa: Exploring options. Renewable and Sustainable Energy Reviews **20**(0), 336 – 352 (2013). DOI http://dx.doi.org/10.1016/j.rser.2012.11.004
53. Wood, G.: Ethereum: A secure decentralised generalised transaction ledger (2013). URL http://gavwood.com/paper.pdf
54. Zheng, M., Wang, X., Meinrenken, C.J., Ding, Y.: Economic and environmental benefits of coordinating dispatch among distributed electricity storage. Applied Energy **210**, 842 – 855 (2018). DOI https://doi.org/10.1016/j.apenergy.2017.07.095. URL http://www.sciencedirect.com/science/article/pii/S0306261917309686

Chapter 4

DIGITAL MARKETING

> "Science is a way of thinking much more than it is a body of knowledge."
>
> Carl Sagan

Use of operations research tools in digital marketing campaigns involves a set of challenges such as respecting privacy, dealing with big data and optimizing information. This chapter contributes with applied operations research by analyzing the NP-hard problem Targeted Offers Problem in Direct Marketing Campaign (TOPDM). The latter deals with cross-selling campaigns where the goal is to offer the right products to the best set of customers, with the objective is to maximize the expected profit, while, at the same time, respecting the purchasing constraints set by investors and the customers [Oliveira et al., 2017a]. A bi-objective version of this problem is also handled, where the benefit of offering books is calculated based on a bipartite graph (biclique) [Coelho et al., 2017a]. Given the combinatorial nature of the problem and the large volume of data, which can involve real cases with up to one million customers, metaheuristics procedures have been used as an efficient way for solving it. It deals with incentives for clients, while respecting their interests and privacy, thus, this chapter also presents a contribution that deals with blockchain for managing those campaigns. Some contributions in this chapter are:

- Deals with optimization problems applied in the scope of citizens' privacy and modern requirements for data management that are emphasized on SC guidelines;
- Use operations research tools in digital marketing campaigns: with a twofold contribution;

– Considers blockchain for managing direct marketing campaigns.

Papers included in this chapter:

- Coelho, V. N., **Oliveira, T.A.**, Coelho, I. M., Coelho, B. N., Fleming, P. J., Guimarães, F. G., Ramalhinho, H., Souza, M.J., Talbi, E.G. & Lust, T. (2017). Generic Pareto local search metaheuristic for optimization of targeted offers in a bi-objective direct marketing campaign. Computers & Operations Research, 78, 578-587. [Coelho et al., 2017a].

- **Oliveira, T.A.**, Coelho, V. N., Ramalhinho, H., Souza, M. J., Coelho, B. N., Rezende, D. C., & Coelho, I. M. (2017). A VNS approach for book marketing campaigns generated with quasi-bicliques probabilities. Electronic Notes in Discrete Mathematics, 58, 15–22. [Oliveira et al., 2017a];

Appendix A.1:

- **Oliveira, T. A.**, Coelho, V. N., Coelho, I. M., Oliver M. & Ramalhinho H. (2020). Blockchain for Marketing Campaigns with Non-Fungible Discount Tokens.

Coelho, V. N., **Oliveira, T.A.**, Coelho, I. M., Coelho, B. N., Fleming, P. J., Guimarães, F. G., Ramalhinho, H., Souza, M.J., Talbi, E.G. & Lust, T. (2017). Generic Pareto local search metaheuristic for optimization of targeted offers in a bi-objective direct marketing campaign. Computers & Operations Research, 78, 578-587.

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Generic Pareto local search metaheuristic for optimization of targeted offers in a bi-objective direct marketing campaign

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Abstract

Cross-selling campaigns seek to offer the right products to the set of customers with the goal of maximizing expected profit, while, at the same time, respecting the purchasing constraints set by investors. In this context, a bi-objective version of this NP-Hard problem is approached in this paper, aiming at maximizing both the promotion campaign total profit and the risk-adjusted return, which is estimated with the reward-to-variability ratio known as Sharpe ratio. Given the combinatorial nature of the problem and the large volume of data, heuristic methods are the most common used techniques. A Greedy Randomized Neighborhood Structure is also designed, including the characteristics of a neighborhood exploration strategy together with a Greedy Randomized Constructive technique, which is embedded in a multi-objective local search metaheuristic. The latter combines the power of neighborhood exploration by using a Pareto Local Search with Variable Neighborhood Search. Sets of non-dominated solutions obtained by the proposed method are described and analyzed for a number of problem instances.

Keywords: Direct marketing campaign, Sharpe ratio, Cross-selling, Metaheuristics, Multi-objective optimization, Pareto Local Search

1. Introduction

In this paper, we consider a bi-objective metaheuristic for choosing sets of clients in direct-marketing campaigns. We call this problem the Targeted Offers Problem in Direct Marketing (TOPDM) promotional campaigns. Solving the proposed bi-objective problem involves searching for the sets of customers that maximize both the promotion campaign profit and the risk-adjusted return (reward-to-variability index). Candidate solutions should respect campaign operational requirements related to the investors' minimum desired profit, available budget, viability of the product offers and customer constraints.

Since there is uncertainty concerning whether a client will positively react to a new offer, a low-risk cross-selling campaign is sought. In the examples in this paper, we consider instances in which customers with high expected profits are the ones with higher volatility. To handle the reward-to-

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variability concept, a risk-adjusted return measure based on the Sharpe Ratio [1] is proposed, which is a useful index for investment analysis usually adopted by investors facing choices under uncertainties [2].

In the complex scenario of acquiring new customers and improving existing relationships, the field of customer relationship management has been investigated for distinct applications [3, 4]. As mentioned by Cohen [5], the right product should be offered to the right customer at the right time. The goal of recognizing and responding to client requirements remains a significant challenge. Among several techniques, Operational Research (OR) methods have been shown to be a useful and powerful tool that is used by many marketing departments of well-established firms [6, 7, 8].

Bhaskar et al. [9] consider uncertainty in connection with the problem of selecting customers for a cross-selling campaign in a retail bank. A linear fuzzy model based on triangular fuzzy rules over the input parameters (client expected profit and positive responses rates) was developed. A real case involving up to 180,000 clients was employed. These customers were aggregated into a small number of groups according to their expected profits. Cohen [5] studied the case of a promotional campaign in an international bank. The term campaign implied one large pro-active customer contact campaign that comprised 11 distinct offers. Approximately 2.5 million potential customers were evaluated for that campaign. From response models, the specific benefit of each offer for each customer was estimated. In Nobibon et al. [10], a TOPDM was solved using heuristic algorithms and mathematical formulations; in particular, different mathematical programming models were developed. A Branch-and-Price [11] method was designed and the achieved upper bounds were used for comparing seven different optimization methods. The Branch-and-Price proved to be unable to obtain good feasible solutions for instances involving a large set of clients.

Among the proposed techniques, a Tabu Search algorithm [12] exhibited the best performance, using three different Neighborhood Structures (NS). Delanote, Leus & Nobibon [13] included bundled products and the use of multi-channel structures, which allowed the offers to be made through different offering channels (such as mail, email, telemarketing, etc). In Oliveira et al. [14], the dataset of Nobibon et al. [10] was further explored and a new greedy randomized initial solution builder combined with General Variable Neighborhood Search (GVNS) [15] was proposed.

Here, we present a Multi-Objective approach based on the concepts of maximizing profits and searching, at the same time, for a sets of customers with less variability over their expected return (represented by the Sharpe ratio). The use of different NS has been already investigated in the literature and applied for solving several $\mathcal{NP}$-Hard problems [16, 17, 18]. In particular, Nobibon et al. [10] and Oliveira et al. [14] already showed the potential of trajectory search algorithms for the TOPDM. A new concept of Greedy Randomized Neighborhood Structures (GRNS) is also proposed in this paper. The idea of GRNS is to perform neighborhood exploration and reconstruct parts of the neighbor solution by means of a procedure inspired by the metaheuristic Greedy Randomized Adaptive Search Procedure (GRASP) [19]. In order to deal with multiple conflicting objectives, these mechanisms are included in a Two-phase Pareto Local Search with VNS (2PPLS-VNS) [20] to explore the search space in the quest for high quality sets of non-dominated solutions. A Generic 2PPLS-VNS is therefore designed, considering the core of the 2PPLS-VNS and the possibility of using different Neighborhood Exploration (NE) techniques [21]. The problem instances proposed by Nobibon et al. [10] are adapted and used as cases of study.

The main contributions of this current work are:

- use of profit variability measure in connection to the client response;
- consider the Sharpe ratio index for calculating risk-adjusted profit in targeted offers;
- introduction of a bi-objective direct marketing promotional campaign;
- design of a Greedy Randomized Neighborhood Structure;
- generalization of the 2PPLS in order to obtain non-dominated solutions with different neighborhood exploration techniques;

The remainder of this paper is organized as follows. Section 2 describes the TOPDM, as well as an introduction to the uncertainties concerning the client responses and the use of the reward-to-variability concept known as Sharpe ratio. Section 3 describes the proposed framework to engage

the multi-objective TOPDM. Solution representation and its evaluation are described in Sections 3.1 and 3.2, respectively. The greedy randomized solution generator is described in Section 3.3. Section 3.4 presents the NS used to guide the search for non-dominated solutions, as well as the new GRNS concepts, which are described in Section 3.5. The combination of three multi-objective metaheuristics is described in Section 3.6. Section 4 presents the computational experiments, and, finally, followed by a summary and conclusions in Section 5.

2. Problem description

The variant of the TOPDM approached here is composed of a set of clients $C = \{c_1, c_2, ..., c_m\}$ and a set of possible product offers $O = \{o_1, o_2, ..., o_n\}$, quoted for the direct marketing campaign. A cost $c_{ij} > 0$ and profit $p_{ij} \geq 0$ is associated to each customer $i \in C$ if offer $j \in O$ is directed to him/her. For each client $i \in C$, there is a maximum number of offers M_i which would saturate that client. For each product offer $j \in O$, if the product j is selected to be used during the campaign, it should be offered to a minimal number of customers, O_j^{min}. Each product has an initial fixed cost f_j, if it is used in a campaign. A maximum available budget B_j is set by investors of the campaign, which means that the total cost associated with each product offer $j \in O$ should not be bigger than B_j. It is also required a minimum rate of return HR of the whole campaign, known as the Hurdle Rate.

Nobibon et al. [10] considered a fixed probability of a client accepting an offer, which they called r_{ij}. This value was multiplied by the return to the firm, defined as DFV_{ij}, when client i responded positively to an offer of product j. Thus, the expected profit p_{ij} was estimated as $DFV_{ij} \cdot r_{ij}$. In contrast to their work, the bi-objective problem introduced in this paper considers a extra objective related to the variability over each client profit p_{ij}.

Client uncertainties, regarding their responding positively to an offer, usually increase when the expected profits from it are also high [1]. The latter is a well-known fact that investors are used to face. In this sense, a variability parameter, defined as v_{ij}, is associated with each customer $i \in C$ when it is targeted by the offer $j \in O$. The higher the variability/volatility v_{ij}, the higher is the risk of investing in that client.

Figure 1 shows a didactic example of a solution with three clients, $m = 3$, and two products, $n = 2$. It should be emphasized that all clients and products constraints are respected in this considered example. It can be seen that product offer o_1 is targeting the set of clients $\{c_1, c_2, c_3\}$, aggregating a total cost and profit of 7 and 10, respectively. Product offer o_2 is being offered to the set of clients $\{c_1, c_3\}$, consuming an amount of resources equal to 7 and with a total expected profit of 12. The total expected return and cost of this whole campaign are equal to 22 and 19, respectively. It means a total profit of 15.78% over the total amount of money invested over the campaign.

The total variability of the campaign is calculated by the weighted average of each individual volatility v_{ij} multiplied by the amount of profit p_{ij} expected from that client, as can be seen in Eq. (1).

$$V(s) = \frac{\sum_{i \in C} \sum_{j \in P} v_{ij} \cdot p_{ij} \cdot s_{ij}}{\sum_{i \in C} \sum_{j \in P} p_{ij}} \tag{1}$$

Obviously, only active offers are considered in the calculation, using the binary variable s_{ij} for this selection, as will be described ahead in Section 3.1.

Thus, the total risk V of the example given in Figure 1 is:

$$V = \frac{143}{22} = 6.5\%$$

The TOPDM can be reduced to a special case of the 0-1 Multiple Knapsack Problem (MKP). A brief study of this class of problems can be found in [22]. In fact, this analogy can be verified if each possible offer $j \in O$ in the campaign is seen as a knapsack. Thus, in the beginning of the campaign, the knapsack is empty and should be filled with, at least, O_j^{min} offers. The knapsack maximum capacity is the available budget for the campaign of that product. Each client $i \in C$, seen as a single object to be inserted in this knapsack, has an expected profit p_{ij}, an analogy to each object benefit value in the classical Knapsack Problem. The weights of the items in the knapsack are related to the customers in the TOPDM and their respective costs c_{ij}. In this sense, since the MKP belongs to the $\mathcal{NP}$-Hard class, the TOPDM also does.

In 1966, William Forsyth Sharpe (Economics Nobel prize in 1990) introduced the concept of reward-to-variability ratio as a way to measure portfolio performance. The generic Sharpe Ratio [1], as it was later called by academics and financial operators, can be seen as a deviation risk measure, or a

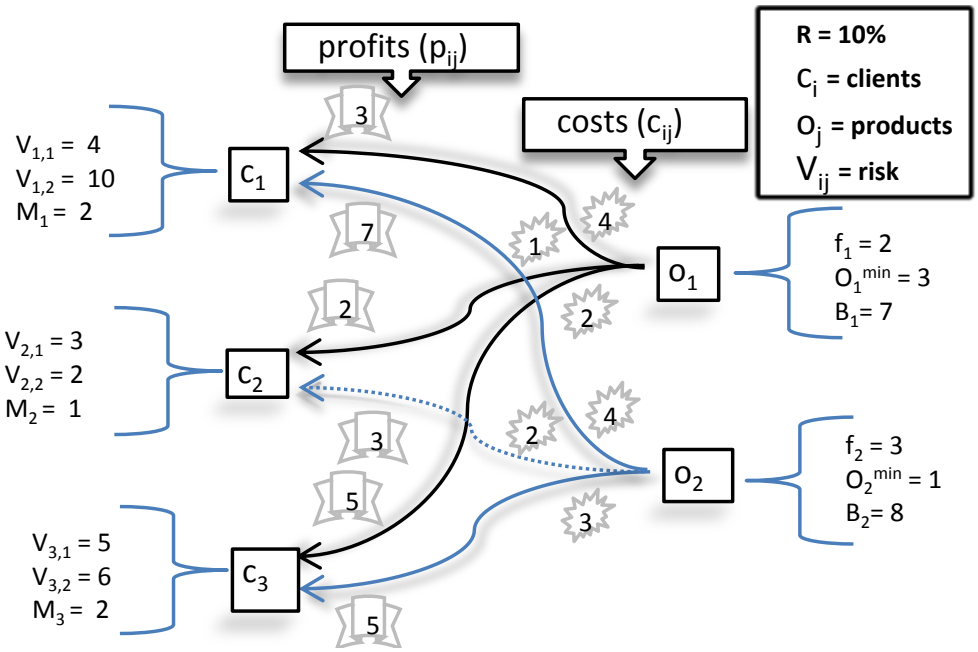

Figure 1: TOPDM example

risk-adjusted return, measuring the difference between the expected return of a fund and the benchmark investment, divided by the residual standard deviation, as presented in Eq. (2). It is often cited as a measure to calculate excess return (or risk premium).

$$SR = \frac{E[RI - RI_f]}{\sigma_R - \sigma_{R_f}} \tag{2}$$

In Eq. (2), $E[\cdot]$ represents the mathematical expectation operator, RI is the return of an asset and RI_f is the risk-free return. In the case that RI_f is a constant risk-free return throughout the analyzed period (as in the current case of study, the marketing campaign), $\sigma_{RI} - \sigma_{RI_f} = \sigma_R$. $E[RI - RI_f]$ is the expected value of the excess of the asset return over the benchmark return.

The Sharpe Ratio has been useful when individual investors face a choice under uncertainty, as it happens in the case of the expected profit from huge direct marketing campaigns. It is able to evaluate not only the profitability, but also the risk faced by the investors of the cross-selling campaign.

3. Methodology

3.1. Solution representation

A solution handled by the metaheuristic algorithm is represented by a binary matrix $R_{|C|\times|O|}$, where C indicates the set of available customers and O represents the possible products to be used in the campaign. If a given cell $s_{i,j}$, with $i \in C, j \in O$, is equal to "1" (true), the product j will be offered to the client i; otherwise, the value would be "0" (false).

Figure 2 shows the solution representation for the example previously given in Figure 1.

$$s = \begin{bmatrix} & o_1 & o_2 \\ c_1 & 1 & 1 \\ c_2 & 1 & 0 \\ c_3 & 1 & 1 \end{bmatrix}$$

Figure 2: Solution representation example

3.2. Objective functions and evaluation

A solution s is evaluated regarding two conflicting objective functions, that should be maximized:

- $f^P(s)$, Eq. (3), which measures the total profit of the campaign;

- $f^{SR}(s)$, Eq. (5), which measures the total reward-to-variability of the whole investment, inspired from the Sharpe Ratio SR index;

$f^P(s)$ is seen as the total return of the marketing campaign and is calculated following Eq. (3). Basically, it is the total expected profits p_{ij}, given the set of active clients i targeted by offers j, minus the total costs TC, described in Eq. 4.

The adaptation of the generic Sharpe Ratio for the TOPDM can be seen in Eq. (5). As mentioned in Section 2, the classic indicator has a variable related to the risk free investment. Here, the Hurdle Rate HR of the campaign, settled by the investors, is used instead of the risk-free R_f. Thus, we define $HR = R_f$, which is constant during the whole campaign, since investors will not change their minimum total profit. Finally, the original σ_R is now seen as the total risk of the campaign, summed into variable $V(s)$, already described in Eq. (1).

$$f^P(s) = \sum_{i \in C} \sum_{j \in P} p_{ij} s_{ij} - TC(s) \tag{3}$$

$$TC(s) = \sum_{i \in C} \sum_{j \in P} c_{ij} s_{ij} - \sum_{j \in P} f_j y_j \tag{4}$$

$$f^{SR}(s) = \frac{\frac{f^P(s)}{TC(s)} - HR}{V(s)} \tag{5}$$

3.3. Building an initial solution

A novel greedy randomized solution generator, adapted from the greedy randomized procedure proposed by Oliveira et al. [14], is described in this section. The procedure is inspired by the pure greedy procedure of Van Praag [23].

The pseudo-code of this procedure is described in Algorithm 1. Its main parameters are described below:

- Set A contains available customers which are not saturated and can receive more offers;
- set S is the set of products already selected to the campaign;
- variable tp measures campaign current total profit;
- variable tc indicates current total cost;
- set LC_j is a list of possible clients to be targeted by the product offers j , greedily ordered;
- set LRC_j is a restricted list of possible clients for a product offer j, ordered according to the greedy randomized parameter $\gamma \in [0, 1]$;
- set CS_j is the current set of selected clients of j;
- variables C_j, P_j and PR_j are the current costs, profits and campaign profit, respectively, of the list of clients in CS_j.

Algorithm 1: BuildGRASPSolution

```
   Input: γ ∈ [0, 1]
   Output: initial solution s
1  tp ← 0, tc ← 0, A ← C and S ← ∅ .
2  foreach j ∈ P do
3      foreach i ∈ M do
4          ANPP_ij ← (p_ij v_ij − c_ij) / c_ij
5      end
6  end
7  forall j ∉ S do
8      LC_j ← set of clients i ∈ A sorted in decreasing
       order by its ANPP_ij
9      CS_j ← ∅, C_j ← 0 and P_j ← 0
10     for |CS_j| ≤ O_j do
11         LRC_j ← ∅
12         for c = 0 ≤ γ · |LC_j| do
13             LRC_j ← LRC_j ∪ {LC_j(c)}
14         end
15         Select a client i ∈ LRC_j at random
16         CS_j ← CS_j ∪ {i}
17         LC_j ← LC_j \ {i}
18     end
19     C_j ← sum of all the costs c_ij from clients i ∈ CS_j
20     P_j ← sum of all benefits p_ij from clients i ∈ CS_j
21     PR_j ← P_j − C_j − f_j
22 end
23 Select j* with the highest PR_j* > 0 such that
   [C_j* ≤ B_j*] & [ (tp + P_j*) ≥ (1 + HR)(tc + C_j* + f_j*)]
24 if ∃j* then
25     S ← S ∪ {j*}
26     tp ← tp + P_j* and tc ← tc + C_j* + f_j*
27     Update targeted offers of product j* in solution s
28     Update A by removing all saturated clients
29     Back to line 7
30 end
31 foreach active client i ∈ A do
32     foreach j ∈ S do
33         if p_ij > c_ij and the offer j directed to the
           client i generates a feasible solution then
34             s_ij ← 1
35         end
36     end
37 end
38 return s
```

Line 1 of Algorithm 1 initializes auxiliary variables and sets. Variables tp and tc are used in line

23 for verifying if the minimum hurdle rate HR is satisfied. From lines 2 to 6, a metric called ANPP measures clients profitability and variability, which is an adaptation of the one presented in Nobibon et al. [10]. It measures the amount of reward related to the costs, that is being invested, multiplied by the risk of that client.

Between lines 7 and 22, the "best" set of clients with respect to the greedy parameters γ is defined. In line 8 the clients are sorted in decreasing order of their $ANPP$ values. That means that clients with higher profits are the most desired ones, but, a balance with its volatility is also done. From lines 10 to 18 the minimum number of clients O_j for the product offer j is selected. The restricted number of candidates $\gamma \cdot |LC_j|$ is added to the set LRC_j.

The best product j^* with the highest PR_j values, satisfying all operational constraints, is selected in the line 23. Clients targeted to receive offer j^* are inserted in solution s and the algorithm returns to line 7. If there are no more available offers nor the minimum number of available clients, the procedure goes to its final steps from lines 31 to 37, when the solution s is refined and improved. At this step, all available clients are sought to receive more offers, if it generates feasible solutions and improves the campaign total profit.

3.4. Neighborhood structures

To explore the search space of the TOPDM, NS were adapted from Nobibon et al. [10] and Oliveira et al. [14]. In their works, three different NS were used, which are briefly described below. It should be noted that the initial solution generator (Section 3.3) and these two NS are both designed to keep feasibility and walk through a feasible search space.

Swap Clients Intra – $NS^{SC^{Intra}}(s)$**:** This movement consists in swapping two positions, $l, m \in C$ of a given product $j \in O$, such that $s_{l,j} = s_{m,j}$ and $s_{m,j} = s_{l,j}$.

Swap Clients Inter – $NS^{SC^{Inter}}(s)$**:** Similar to the movement $N^{TC-Intra}(s)$, but in this case, two positions from different products $i, j \in O$ are swapped, e.g., $s_{l,i} = s_{m,j}$ and $s_{m,j} = s_{l,i}$.

$NS^{SC^{Intra}}(s)$ or $NS^{SC^{Inter}}(s)$ represent NS involving small changes in the solution, which is desirable for local search. However, the small steps performed in these NS might lead to slow convergence in large problems. For example, the largest problem dealt by Nobibon et al. [10], composed of 10,000 clients and 15 products, would give a search space with almost 50 millions different moves for $NS^{SC^{Intra}}(s)$.

In the next section, a novel Greedy Randomized NS is described, as well as an example of its use.

3.5. Greedy Randomized NS

The concept of a Greedy Randomized NS (GRNS) derives from the same principle of GRASP [19], where a semi-greedy constructive method builds a solution step by step, inserting elements from a list of candidates (line 8 of Algorithm 1), according to a sorting criterion. This criterion is generally related to the best parts of the solution that are able to minimize the desired greedy function. An example was already presented in line 4 of Algorithm 1, where ANPP criterion balances profit and volatility, both related to the objective functions described in Section 3.2.

An example of a GRNS is the neighborhood $GRNS^{SP}(s)$, described in algorithm 2, adapted from $NS^{SP}(s)$ [10].

Swap Products – $NS^{SP}(s)$**:** exchanges two bits from two different columns $i, j \in O$ of a given solution s, such that $y_i = 1$ and $y_j = 0$. Thus, a product offer which is not being used in the campaign ($y_j = 0$) can be now part of the active set of products to be used during the campaign. A new product is added if, and only if, there are, at least, O_j available clients for receiving offers (after removing offers from y_i).

The main difference between the strategy introduced here is that a random product from the active set of products is removed (line 2 of Algorithm 2) and a new random one is selected from the set of the products offers which are not being used in the campaign, as can be seen in line 3. As already mentioned, a new product is only inserted in the campaign if there is a minimum O_j available clients in the set V and if operational constraints are still satisfied.

3.6. Multi-objective local search algorithm

Some recent works in the literature have been trying to standardize and disseminate the use of Dominance-based Multi-objective Local Search (DMLS) methods [21]. The core of the generic algorithm used in this paper combines the flexibility provided by the metaheuristics GRASP [19]

Algorithm 2: $GRNS^{SP}(s)$ move generation

Input: solution s, $\gamma^{GRNS} \in [0,1]$, set of available clients A, set of active products S
Output: move $m(s)$

1 $j^{remove} \leftarrow$ product offer from the set of active offers S chosen at random
2 Update A and S by removing all targeted offers from j^{remove}
3 $j \leftarrow$ pick product offer at random from the set of inactive offers $\{O - S\}$
4 **foreach** $i \in A$ **do**
5 $\quad ANPP_{ij} \leftarrow \frac{(p_{ij} v_{ij} - c_{ij})}{c_{ij}}$
6 **end**
7 Call the same procedure from Lines 8 to 18 of Algorithm 1, considering greedy parameter γ^{GRNS}
8 Update targeted offers of product j in solution s
9 Update A by removing all saturated clients
10 **foreach** *active client* $i \in A$ **do**
11 $\quad$ **if** $p_{ij} > c_{ij}$ *and the offer* j *directed to the client* i *generates a feasible solution* **then**
12 $\quad\quad s_{ij} \leftarrow 1$
13 $\quad$ **end**
14 **end**
15 **return** s

and Two-phase Pareto Local Search with VNS (2PPLS-VNS) [20]. Pareto Local Search [24, 25, 26] is a straightforward extension of the classical Hill-Climbing method. Nevertheless, we design a even more generic method, able to perform local searches considering different neighborhood exploration techniques. For those interested in this topic, different mechanisms for DMLS were pointed out by Liefooghe et al. [21] and the variants based on multi-objective variable neighborhood search methods were discussed by Duarte et al. [27]. The abbreviation G2PPLS-VNS is defined for our Generic 2PPLS-VNS, with its pseudo-code outlined in Algorithm 3.

In line 1 of Algorithm 3, an initial set of non-dominated solutions is generated by the procedure Pareto Front Builder (*pfBuilder*), described in Algorithm 4. Procedure *pfBuilder* generates $graspMax$ solutions and calls addSolution (Algorithm 5, extracted from [28]) procedure for filtering those that are non-dominated.

Algorithm 3 performs a Pareto Local Search according to the 2PPLS-VNS designed by Lust & Teghem [20]. This algorithm handles an auxiliary set P_a that contains the solution added in each iteration.

Line 7 explores the neighbors of each solution p from population P using any Neighborhood Explo-

Algorithm 3: Generic 2PPLS with VNS

Input: Neighborhoods $N_k(x)$, $graspMaxSol$ and $\gamma^{maxRange}$
Output: Approximation of the efficient set Xe

1 $P_0 \leftarrow$ pfBuilder($graspMax$,$\gamma^{maxRange}$)
2 Xe and $P \leftarrow P_0$
3 $P_a \leftarrow \emptyset$
4 $k \leftarrow 1$
5 **while** $k \leq r$ **do**
6 $\quad$ **forall** $p \in P$ **do**
7 $\quad\quad$ NE($Xe, p, Added, N_k(x), ...$)
8 $\quad\quad$ **if** $Added = true$ **then**
9 $\quad\quad\quad$ update P_a with the new individuals added to Xe;
10 $\quad\quad$ **end**
11 $\quad$ **end**
12 $\quad$ **if** $P_a \neq \emptyset$ **then**
13 $\quad\quad k \leftarrow 1$
14 $\quad\quad P \leftarrow P_a$ and $P_a \leftarrow \emptyset$
15 $\quad$ **else**
16 $\quad\quad k \leftarrow k + 1$
17 $\quad\quad P \leftarrow Xe \setminus \{x \in Xe \mid$ Pareto local optimum for $N_k(x)\}$;
18 $\quad$ **end**
19 **end**
20 **retorna** Xe

Algorithm 4: pfBuilder

Input: $graspMaxSol$ and $\gamma^{maxRange}$
Output: Approximation of the efficient set Xe

1 **for** $i \leftarrow 1$ ***To*** $graspMaxSol$ **do**
2 $\quad \gamma \leftarrow$ random value $in [0, \gamma^{maxRange}]$
3 $\quad s \leftarrow BuildGRASPSolution(\gamma)$
$\quad Xe' \leftarrow addSolution(Xe, s, f(p))$
4 **end**
5 **return** Xe

Algorithm 5: addSolution

Input: Non-dominated population Xe; Solution s and its corresponding evaluations $z(s)$

Output: Xe and Added (optional)

```
1  Added ← true
2  forall x ∈ Xe do
3  |  if z(x) ⪯ z(s) then
4  |  |  Added ← false
5  |  |  Break
6  |  end
7  |  if z(s) ≺ z(x) then
8  |  |  Xe ← Xe \ x
9  |  end
10 end
11 if Added = true then
12 |  Xe ← Xe ∪ s
13 end
14 return Xe
```

Algorithm 6: Exhaustive Neighborhood Exploration (ENE)

Input: Initial approximation of the efficient set Xe, solution p and Neighborhood $N(p)$

Output: Xe and Added (optional)

```
1 forall p' ∈ N(p) do
2 |  addSolution(Xe, p', f(p'), Added)
3 end
4 retorna Xe
```

Algorithm 7: Random Neighborhood Exploration (RNE)

Input: Initial approximation of the efficient set Xe, solution p, Neighborhood $N(p)$ and number of random moves $mMax$

Output: Xe and Added (optional)

```
1 for m = 1 to mMax do
2 |  p' ← random move of N(p)
3 |  addSolution(Xe, p', f(p'), Added)
4 end
5 retorna Xe
```

ration (NE) technique. In our designed strategy, the procedure NE, an abbreviation for any Neighborhood Exploration techniques, should update the set of non-dominated solutions X_e. An example of an Exhaustive Neighborhood Exploration (ENE) is given in Algorithm 6, which would result in the classical PLS algorithm. ENE procedure generates all possible neighbors from lines 1 to 3. However, a partial neighborhood exploration can be done with random moves, as exemplified in Algorithm 7.

If, at least one new non-dominated solution was found during the NE procedure (line 12 of Algorithm 3), the local search starts again from the first NS (line 13) and will search over the new obtained ones. Otherwise, if no new solution was found, line 16 makes the algorithm jump to the next available NS. A speed up is made in line 17, in a such way that the method will not repeat the neighborhood search over visited neighbors.

4. Computational experiments

This section is divided into six subsections. Section 4.1 presents the computational resources, some considerations about the code and algorithm parameters. Section 4.2 introduces the cases of study used in this paper. Section 4.3 checks the ability of the constructive in generating diversified solutions for composing initial sets of non-dominated solutions. Section 4.4 analyses the GRNS proposed in this paper. Section 4.5 reports the results considering all features of the proposed algorithm. Finally, Section 4.6 describes two Pareto fronts obtained using the proposed methodology.

4.1. Basic configurations

The metaheuristic algorithm was implemented in C++ in the framework OptFrame 2.2 [1] [29]. This framework has been successfully applied to other problems in the literature, as can be seen in [30, 31, 18].

The tests were carried out on an OPTIPLEX 9010 Intel Core i7-3770, 3.40 x 8 GHZ with 32GB of RAM, with operating system Ubuntu 14.04 precise, and compiled by g++ 4.8.4, using the Eclipse Kepler Release.

4.2. Datasets

The set of instances was taken from Nobibon et al. [10]. The test problems comprised cases with 300, 2,000 and 10,000 clients, respectively small, medium and large size cases. For each different set

[1] Available at http://sourceforge.net/projects/optframe/

of clients, three instances with different number of possible offers were used: 5, 10 and 15 available products for the promotional campaign.

The expected return p_{ij} for each offer $j \in O$ directed to customer $i \in C$ is an integer between 0 and 16. Clients were grouped according to their expected profit. Volatility values v_{ij} were generated for each group, as described in Eq. (6). A maximum volatility of 0.6 can be returned by this formula.

$$v_{ij} = \begin{cases} 0.01, & \text{if} \quad p_{ij} < 3 \\ 0.05, & \text{if} \quad 3 \leq p_{ij} < 5 \\ 0.1, & \text{if} \quad 5 \leq p_{ij} < 8 \\ 0.25, & \text{if} \quad 8 \leq p_{ij} < 11 \\ 0.4, & \text{if} \quad 11 \leq p_{ij} < 14 \\ 0.6, & \text{if} \quad p_{ij} \geq 14 \end{cases} \tag{6}$$

4.3. Checking GRASP ability of obtaining non-dominated solutions – pfBuilder procedure

The first batch of experiments sought to analyze the ability of the constructive procedure in finding good initial sets of non-dominated solutions, i.e., initial estimates of the Pareto front. Different sizes of the initial population and GRASP greedy parameters were verified: $graspMaxSol = [1, 10, 100, 500, 1000, 3000, 5000, 10000]$ and $\gamma^{maxRange} = [0.05, 0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9, 1]$. The batch was composed of 11673 executions, considering all possible configurations of both parameters.

Furthermore, the new $ANPP$ strategy, which includes the variability v_{ij} in the original NPP calculus was also analyzed. In this sense, both sorting strategies $ANPP$ and NPP were considered for the constructive procedure.

Obtained sets of non-dominated solutions were evaluated according to:

1. Hypervolume (HV) [32] quality indicator (using the computational tool provided by Beume et al. [33]);
2. Number of non-dominated solutions.

Figure 3 shows one interaction plot between analyzed parameters and these Quality Indicators (QI). Values were normalized for the HV by subtracting the minimum values and dividing the result by the range of each indicator,

$$\frac{QI - min(QI)}{max(QI) - min(QI)}$$

Dashed lines show the standard deviation while the continuous lines indicate average values. The higher the $\gamma^{maxRange}$, the more non-dominated solutions could be found, since solutions can be generated with more randomness. We decide to set this parameter to $\gamma^{maxRange} = 0.8$, providing an interesting balance between the HV, number of non-dominated solutions and standard deviation.

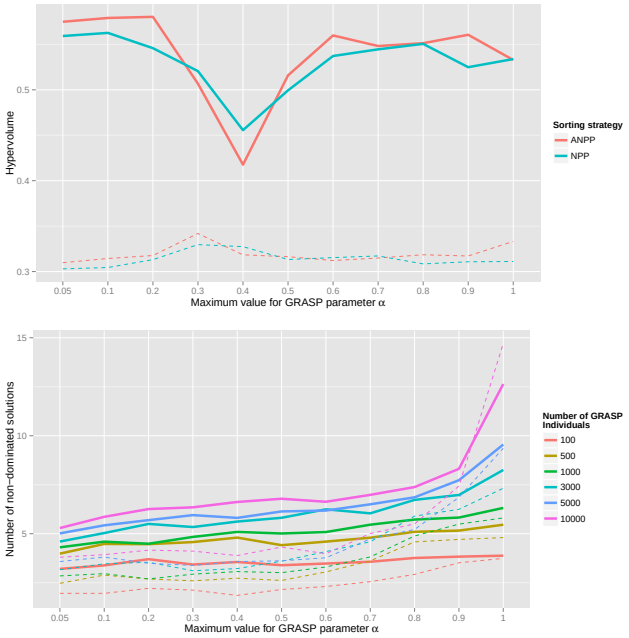

Figure 3: Interaction plots of number of initial solutions, $\gamma^{maxRange}$ parameters and sorting strategy

4.4. Checking PLS with the GRNS

This second batch intended to check if the proposed GRNS was able to improve the quality of the initial estimates of the Pareto Front. Thus, we verify its effectiveness regarding different greedy parameters $\gamma^{GRNS} = \{0.05, 0.1, 0.2, 0.5, 0.7, 0.9, 1\}$, $iterMax^{GRNS} = \{1, 5, 10, 50, 100\}$ and $graspMaxSol = [1, 10, 100, 500]$ In the same way as proceeded in the last batch of experiments, 5,000 random runs, with a restricted computational time of 5 minutes, were performed considering all combinations of these values.

This randomized greedy NS can be exhaustively searched following the procedure defined in Algorithm 6. The number of neighbors is the amount of possible swaps between products (105 for the case involving 15 products, $\frac{15*14}{2}$). However, due to the greedy parameter γ^{GRNS}, different clients can be

targeted each time a move is generated. Figure 4 illustrates the obtained results considering both aforementioned QI plus a diversity indicator, calculated with the Δ metric [34];

As expected, whenever an ENE is performed ($iterMax^{GRNS}$), the quality of the estimate set of non-dominated solutions is improved. Thus, parameter γ^{GRNS} was fixed to 0.1 for the following analysis.

4.5. Checking complete Generic 2PPLS with VNS

This third and last batch of experiments aimed at analyzing the performance of the proposed G2PPLS-VNS. For this purpose, two different configurations were analyzed:

1. searching from the largest to the smallest neighborhoods, $l2s$ ($NS^{SC^{Inter}}(s)$, $NS^{SC^{Intra}}(s)$ and $GRNS^{SP}(s)$, respectively);
2. exploring from the smallest to the largest neighborhoods, $s2l$, ($GRNS^{SP}(s)$, $NS^{SC^{Intra}}(s)$ and $NS^{SC^{Inter}}(s)$, respectively).

In total, $2,500$ runs were performed, checking algorithm performance for a starting of

As pointed out in Section 3.4, it would be a huge computational effort to run ENE for the neighborhood $NS^{SC^{Inter}}(s)$ and $NS^{SC^{Intra}}(s)$. In this sense, two RNE (Algorithm 7) were created for each of these NS with $mMax = 1000$. The first two graphics of Figure 5 show the HV of the final estimate of the Pareto Front (after G2PPLS-VNS refinement) and of its respective initial set of non-dominated solutions, while the third one shows the HV improvement.

4.6. Obtained sets of non-dominated solutions

Two different test problems were used for illustrating the Pareto Fronts that can be obtained using the proposed methodology. A single run of 10 minutes was performed for each case and the obtained sets of non-dominated solutions (or parts of it) are illustrate in Figure 6 and Table 1.

Table 1 shows characteristics of some of the non-dominated solutions obtained in each case. As can be noticed, those different solutions illustrate several possible scenarios for conducting the promotional campaign. Each of these possible sets of targeted offers indicate a specific expected profit and Sharpe Ratio associated to it.

Finally, Figure 7 computes the maximum expected profit of each execution from the batch of experiments of this section. In order to compare the performance of the proposed algorithm in terms of minimizing a single objective, the GAP metric ($gap_i^n = \frac{f_i^* - f_i^n}{f_i^*}$) was used, with f_i^* being the best known result for a given test-problem and f_i^n the value obtained by each algorithm. Average gaps of the G2PPLS-VNS algorithm are compared with the single values reported from a Tabu Search algorithm (H8) [10].

5. Conclusions and extensions

5.1. Summary and final considerations

In this paper, a bi-objective direct-marketing promotional campaign was discussed by simultaneously optimizing campaign profits and a reward-to-variability index, adapted from the Sharpe Ratio. A multi-objective DMLS metaheuristic was proposed for searching for sets of non-dominated solutions.

Due the large number of neighborhoods that can be searched, a generic Pareto Local Search was introduced. In order to produce a diversified initial estimate of the Pareto Front, a greedy randomized initial solution builder was proposed for dealing with the concept of volatility. Furthermore, a special case involving a Greedy Randomized Neighborhood Structure, which reconstructs parts of the solution, was described and evaluated.

By adapting test problems from the literature, different characteristics from the obtained Pareto Fronts were described and analyzed. Sharpe ratio index was able to regulate the search for low-risk direct marketing campaigns, providing a trade-off between campaign total profit and the groups of clients which the offers are directed to.

5.2. Extensions

As future extensions for this research, the current approach should be applied in other types of direct marketing campaigns.

The development of new neighborhood structures might improve the ability of the Pareto Local Search in finding non-dominated solutions from the space of solutions. A parallel version of the method could improve the performance of the model over problems with large amount of data. This approach would take advantage of the multi-core technology that is already integrated in the current machines,

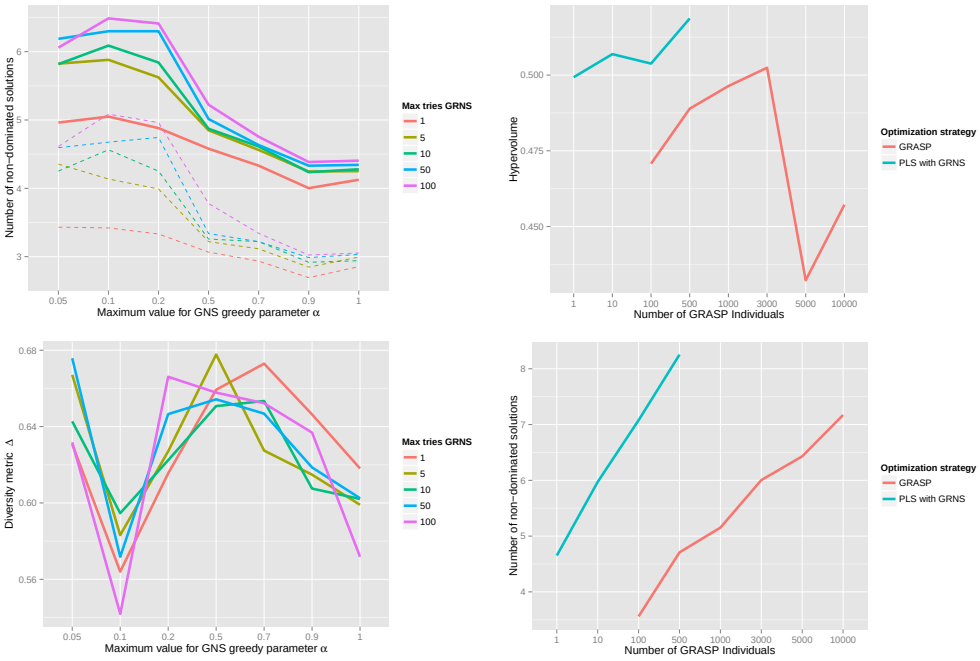

Figure 4: Interaction plots of different indicators, $GRNS$ parameters and optimization strategy

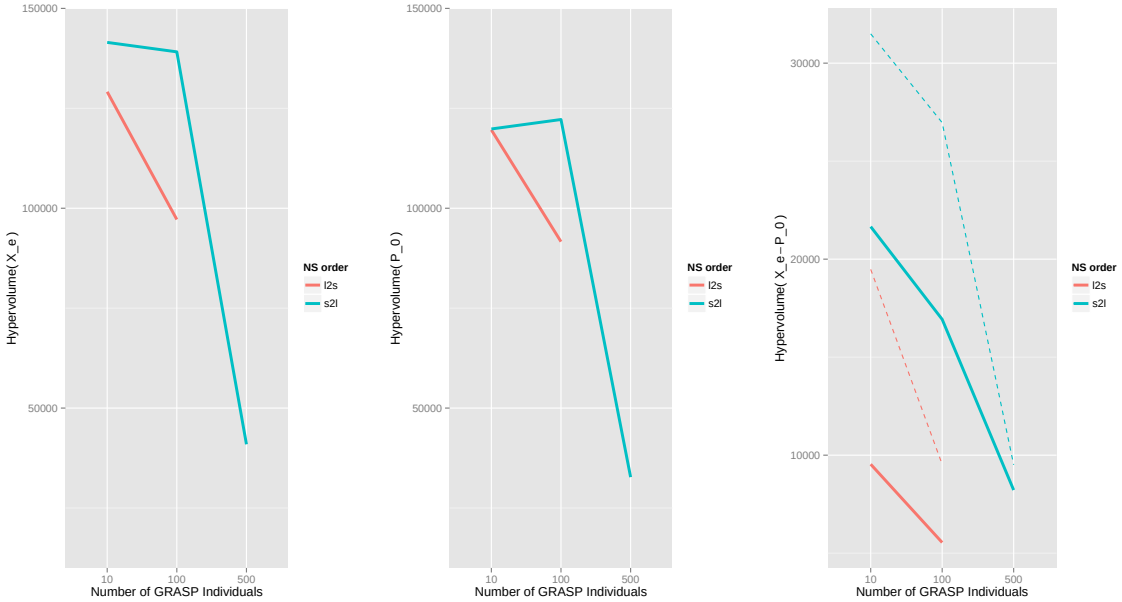

Figure 5: Interaction plots of different indicators, checking local search improvement

Table 1: Targeted offers according to clients risk – Different non-dominated solutions characteristics

Expected profit	Sharpe Ratio	Client risk – v_{ij}					
		0.01	0.05	0.1	0.25	0.4	0.6
Small instance with 100 clients and 15 products							
4599	3.69364	0	2	23	96	192	253
4311	4.11411	0	0	24	99	189	211
4177	4.24447	1	1	40	109	176	196
3990	4.3399	1	9	54	111	172	176
3883	4.37944	1	8	62	121	171	160
3846	4.38868	0	12	66	118	169	158
Large instance "L-10-15-1-l" with 10000 clients and 15 products							
240218	1.63729	4758	7631	14250	14851	15075	15045
239108	1.92499	4617	7018	12989	13586	13816	13811
238344	1.9392	5250	6993	12929	13613	13791	13736
217520	2.03421	5020	6206	11503	12176	12330	12231
217774	2.01374	4464	6210	11552	12145	12347	12294
192945	2.09869	3422	5161	9804	10431	10725	10661
192934	2.12584	3936	5161	9759	10465	10713	10601

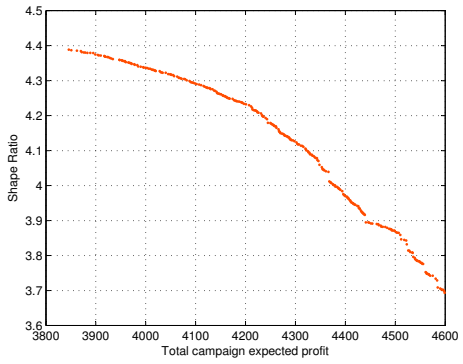

Figure 6: Set of non-dominated solutions for instance "S3-10-15-1-s"

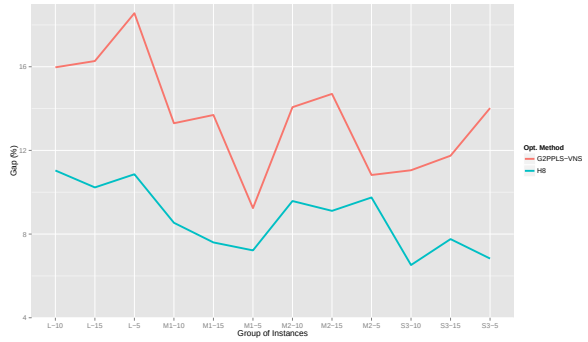

Figure 7: Univariate objective function comparison

and with easy abstraction for this metaheuristic algorithm.

The entire code used in this research is, from this moment, available as example on the OptFrame website. Thus, it is expected that future researchers continue contributing to enhancing the proposed model, increasing its efficiency and improving the tools and ideas presented in this paper.

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References

[1] W. F. Sharpe, The sharpe ratio, The Journal of Portfolio Management 21 (1) (1994) 49 – 58. doi:http://10.3905/jpm.1994.409501.

[2] V. Chow, C. W. Lai, Conditional sharpe ratios, Finance Research Letters 12 (0) (2015) 117 – 133. doi:http://dx.doi.org/10.1016/j.frl.2014.11.001.

[3] S. Murali, S. Pugazhendhi, C. Muralidharan, Modelling and investigating the relationship of after sales service quality with customer satisfaction, retention and loyalty – a case study of home appliances business, Journal of Retailing and Consumer Services 30 (2016) 67 – 83. doi:http://dx.doi.org/10.1016/j.jretconser.2016.01.001.

[4] E. Ghazavi, M. Lotfi, Formulation of customers' shopping path in shelf space planning: A simulation-optimization approach, Expert Systems with Applications 55 (2016) 243 – 254. doi:http://dx.doi.org/10.1016/j.eswa.2016.01.043.

[5] M.-D. Cohen, Exploiting response models: optimizing cross-sell and up-sell opportunities in banking, Informations Systems 29 (4) (2004) 327–341.

[6] V. Mahajan, E. Muller, F. M. Bass, New product diffusion models in marketing: A review and directions for research, in: Diffusion of technologies and social behavior, Springer, 1991, pp. 125–177.

[7] L. L onnstedt, The use of operational research in twelve companies quoted on the stockholm stock exchange, Operational Research Quarterly (1970-1977) 24 (4) (1973) 535–545.
URL http://www.jstor.org/stable/3008331

[8] J. N. Daniel Jr, T. F. Busyn, B. T. Batterman, Marketing research system and method for obtaining retail data on a real time basis, uS Patent 4,972,504 (1990).

[9] T. Bhaskar, R. Sundararajan, P. G. Krishnan, A fuzzy mathematical programming approach for cross-sell optimization in retail banking, Journal of the Operational Research Society 60 (5) (2009) 717–727.

[10] F. T. Nobibon, R. Leus, F. C. Spieksma, Optimization models for targeted offers in direct marketing: Exact and heuristic algorithms, European Journal of Operational Research 210 (3) (2011) 670 – 683.

[11] C. Barnhart, E. L. Johnson, G. L. Nemhauser, M. W. P. Savelsbergh, P. H. Vance, Branch-and-price: Column generation for solving huge integer programs, Operations Research 46 (3) (1998) 316–329.

[12] F. Glover, M. Laguna, Tabu Search, Kluwer Academic Publishers, Boston, 1997.

[13] S. Delanote, R. Leus, F. T. Nobibon, Optimization of the annual planning of targeted offers in direct marketing, J Oper Res Soc 64 (12) (2013) 1770–1779. doi:http://dx.doi.org/10.1057/jors.2012.165.

[14] T. A. Oliveira, V. N. Coelho, M. J. F. Souza, D. L. T. Boava, F. Boava, I. M. Coelho, B. N. Coelho, A hybrid variable neighborhood search algorithm for targeted offers in direct marketing, Electronic Notes in Discrete Mathematics 47 (0) (2015) 205 – 212, the 3rd International Conference on Variable Neighborhood Search (VNS'14). doi:http://dx.doi.org/10.1016/j.endm.2014.11.027.

[15] P. Hansen, N. Mladenovic, J. A. M. Pérez, Variable neighborhood search, European Journal of Operational Research 191 (2008) 593–595.

[16] S. Kirkpatrick, Optimization by simulated annealing: Quantitative studies, Journal of statistical physics 34 (5-6) (1984) 975–986.

[17] N. Mladenovic, P. Hansen, A variable neighborhood search, Computers and Operations Research 24 (1997) 1097–1100.

[18] V. Coelho, A. Grasas, H. Ramalhinho, I. Coelho, M. Souza, R. Cruz, An ils-based algorithm to solve a large-scale real heterogeneous fleet {VRP} with multi-trips and docking constraints, European Journal of Operational Research 250 (2) (2016) 367 – 376. doi:http://dx.doi.org/10.1016/j.ejor.2015.09.047.

[19] T. A. Feo, M. G. C. Resende, Greedy randomized adaptive search procedures, Journal of Global Optimization 6 (1995) 109–133.

[20] T. Lust, J. Teghem, D. Tuyttens, Very large-scale neighborhood search for solving multiobjective combinatorial optimization problems, in: R. Takahashi, K. Deb, E. Wanner, S. Greco (Eds.), Evolutionary Multi-Criterion Optimization, Vol. 6576 of Lecture Notes in Computer Science, Springer Berlin / Heidelberg, 2011, pp. 254–268.

[21] A. Liefooghe, J. Humeau, S. Mesmoudi, L. Jourdan, E.-G. Talbi, On dominance-based multiobjective local search: design, implementation and experimental analysis on scheduling and traveling salesman problems, Journal of Heuristics 18 (2) (2012) 317–352. doi:10.1007/s10732-011-9181-3.

[22] H. Kellerer, U. Pferschy, D. Pisinger, Knapsack problems, Springer, 2004.

[23] N. V. Praag, Optimization of promotion campaigns using tabu search, Master's thesis, Faculty of Business and Economics, KULeuven (2010).

[24] L. Paquete, M. Chiarandini, T. Stützle, Metaheuristics for Multiobjective Optimisation, Springer Berlin Heidelberg, Berlin, Heidelberg, 2004, Ch. Pareto Local Optimum Sets in the Biobjective Traveling Salesman Problem: An Experimental Study, pp. 177–199. doi:10.1007/978-3-642-17144-4_7.

[25] E. Angel, E. Bampis, L. Gourvès, Metaheuristics for Multiobjective Optimisation, 2004, Ch. A Dynasearch Neighborhood for the Bicriteria Traveling Salesman Problem, pp. 153–176. doi:10.1007/978-3-642-17144-4_6.

[26] E.-G. Talbi, M. Rahoual, M. H. Mabed, C. Dhaenens, Evolutionary Multi-Criterion Optimization: First International Conference, EMO 2001 Zurich, Switzerland, March 7–9, 2001 Proceedings, Springer Berlin Heidelberg, Berlin, Heidelberg, 2001, Ch. A Hybrid Evolutionary Approach for Multicriteria Optimization Problems: Application to the Flow Shop, pp. 416–428. doi:10.1007/3-540-44719-9_29.

[27] A. Duarte, J. J. Pantrigo, E. G. Pardo, N. Mladenovic, Multi-objective variable neighborhood search: an application to combinatorial optimization problems, Journal of Global Optimization 63 (3) (2015) 515–536. doi:10.1007/s10898-014-0213-z.

[28] T. Lust, J. Teghem, Two-phase Pareto local search for the biobjective traveling salesman problem, Journal of Heuristics 16 (2010) 475–510.

[29] I. M. Coelho, P. L. A. Munhoz, M. N. Haddad, V. N. Coelho, M. M. Silva, M. J. F. Souza, L. S. Ochi, A computational framework for combinatorial optimization problems, in: VII ALIO/EURO Workshop on Applied Combinatorial Optimization, Porto, 2011, pp. 51–54.

[30] M. J. F. Souza, I. M. Coelho, S. Ribas, H. G. Santos, L. H. C. Merschmann, A hybrid heuristic algorithm for the open-pit-mining operational planning problem, European Journal of Operational Research 207 (2) (2010) 1041–1051.

[31] V. N. Coelho, I. M. Coelho, B. N. Coelho, A. J. Reis, R. Enayatifar, M. J. Souza, F. G. Guimarães, A self-adaptive evolutionary fuzzy model for load forecasting problems on smart grid environment, Applied Energy 169 (2016) 567 – 584. doi:http://dx.doi.org/10.1016/j.apenergy.2016.02.045.

[32] E. Zitzler, L. Thiele, Multiobjective optimization using evolutionary algorithms - a comparative case study, in: A. Eiben, T. Back, M. Schoenauer, H.-P. Schwefel (Eds.), Parallel Problem Solving from Nature - PPSN V, Vol. 1498 of Lecture Notes in Computer Science, Springer Berlin / Heidelberg, 1998, pp. 292–301.
URL http://dx.doi.org/10.1007/BFb0056872

[33] N. Beume, C. Fonseca, M. Lopez-Ibanez, L. Paquete, J. Vahrenhold, On the complexity of computing the hypervolume indicator, Evolutionary Computation, IEEE Transactions on 13 (5) (2009) 1075 –1082. doi:10.1109/TEVC.2009.2015575.

[34] K. Deb, A. Pratap, S. Agarwal, T. Meyarivan, A fast and elitist multiobjective genetic algorithm: NSGA-II, Evolutionary Computation, IEEE Transactions on 6 (2) (2002) 182–197. doi:10.1109/4235.996017.

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A VNS approach for book marketing campaigns generated with quasi-bicliques probabilities

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Abstract

This paper focuses on Book Marketing Campaigns, where the benefit of offering each book is calculated based on a bipartite graph (biclique). A quasi Biclique problem is assessed for obtaining the probabilities of success of a given client buy a given book, considering it had received another book as free offer. The remaining optimization decision problem can be solved following the Targeted Offers Problem in Direct Marketing Campaigns. The main objective is to maximize the feedback of customers purchases, offering books to the set of customers with the highest probability of buying others ones from its biclique and, at the same time, minimizing campaign operational costs. Given the combinatorial nature of the problem and the large volume of data, which can involve real cases with up to one million customers, metaheuristics procedures have been used as an efficient way for solving it. Here, a hybrid trajectory search based algorithm, namely GGVNS, which combines the

Greedy Randomized Adaptive Search Procedures and General Variable Neighborhood Search, is used. The strategy for generating the quasi Biclique problem is described and a new instance generator for the TOPDMC is introduced. Computational results regarding the GGVNS algorithm shows it is able to find useful and profitable sets of clients.

Keyword: Books marketing, Campaigns, Targeted offers problem, Quasi-Biclique, General Variable Neighborhood Search and Operational Research

1 Introduction

Currently the field of literature has undergone several transformations, in particular, with the advent of new technologies and mobile devices, reading is becoming increasingly widespread. Big-data datasets regarding the purchase of books will keep growing. Edges connecting clients and books can be used to represent links between them. Mining information from those bipartite graphs (biclique) is the task introduced and discussed in this paper.

The problem of finding suitable books to be offered to a given client can fit the scope of the Targeted Offer Problem in Direct Marketing Campaign (TOPDMC) [5], that seeks to select the most profitable set of customers for offering products in Direct Marketing campaigns. Generally speaking, the main goal is to find an appropriate set of clients to receive a book offer, maximizing campaign profits while respecting operational requirements.

We consider the real case where a first book is offered as gift [3], expecting that this fact will reinforce and strength biclique connections (as can be seen in Figure 1). Considering this new offer, the probability of that client buying other recommended books, from its quasi-biclique, is measured. Examples of free samples and consumers purchase have been studied in different sectors [3]. Lammers [3] verified that sampling significantly increased the immediate sales of chocolates, however, most part of the clients purchased chocolate varieties other than the variety sampled. Cosmetic companies have been doing free sampling [1] and still appear to be open for new strategies based on Artificial

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Intelligence (AI) tools.

The sum of the probabilities of a given client i buying a book, considering it received book j as an offer, are used for creating an instance of the TOPDMC. The latter is solved using a previous designed Variable Neighborhood Search algorithm. Figure 1 represents a single biclique, connecting clients and books. Books may have already been read or might be offered or recommended during the marketing campaign. Thus, each client i might had read some books, let consider a set of books $B_i = \{b_i^1, ..., b_i^b, ..., b_i^m\}$, where m is number of books read by that client. In this case, an edge connects clients i to each read book b_i^b from this set B_i. In the depicted example, the following books were already read, bought or received as gift: $B_1 = \{b_1^3\}$; $B_2 = \{b_2^1, b_2^2\}$; $B_3 = \{b_3^3, b_3^4\}$. As can be noticed: books 1, 2 and 4 still can be offered or recommended to the client 1; book 1 is being offered as a free sample while books 2 and 4 are being recommended. Similar cases are exemplified for clients 2 and 3.

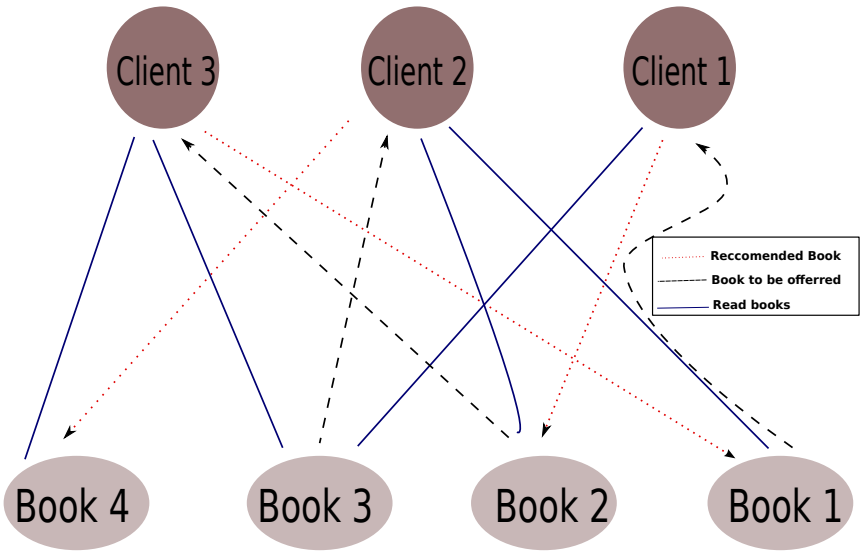


Fig. 1. Quasi-Biclique with books to be offered and recommended

AI mining tools associated with marketing response models are changing the central role of information previous labeled as useless. Datasets generated over a long period of time, or even short time ones with high measuring rate, are being mined and sought for optimization. The TOPDMC is an special case of DM campaigns, where OR is used to optimize the profit from the values generated by those response models.

Given a set of clients $C = \{c_1, ..., c_m\}$ and a set of offers $B = \{b_1, ..., b_n\}$, a cost d_{ij} and profit r_{ij} are associated to each book offer $j \in B$ targeted to a specific customer $i \in C$. Those estimated parameters d_{ij} and r_{ij} are usually obtained from the aforementioned marketing response models. For each client $i \in C$, there is a number of maximum offers M_i, which indicates the maximum number of offers that a client i is willing to receive. For each product offer $j \in B$, there is a strict minimum number of products O_j^{min} that should be offered during the campaign, a minimum expected profit R (also known as hurdle rate), an available budget B_j and, finally, a fixed cost f_j if the product j is chosen to be disseminated in that campaign.

The 0-1 Multiple Knapsack Problem is a special case of the TOPDMC. In this sense, since the Multiple Knapsack Problem belongs to the $\mathcal{NP}$-Hard class, the TOPDMC also does. Different mathematical formulations were exploited, and compared, in the work of Nobibon et al. [5].

2 Quasi-Bicliques generation and probabilities extractions

The generator consider bipartite graphs that have been clustered before in some disjoint bicliques. This problem could be solved by finding the minimum editing distance in order to find clustered bicliques, that become quasi-bicliques when these extra edges are removed. Although the clustering problem is NP-hard itself, we manage to generate instances in polynomial time. The process is described in the following steps:

(i) Start with a fully connected biclique graph (clients versus books);

(ii) Randomly choose clients and books in order to create bicliques;

(iii) Randomly remove edges from each biclique maintaining the connectivity (respecting at least $maxClientsPerBiclique$ and $maxBooksPerBiclique$ per biclique), thus forming quasi-bicliques;

(iv) Calculate the probability for each pair (client, book), after the insertion of an extra edge.

The calculation of the probability is done as follows. Given a new edge (c, b) not present in the quasi-biclique (C, B) containing the client c, insert this edge in the quasi-biclique. The probability of client c to buy another recommended book b' is given by $\delta(b')/|B|$, that is, the more connected the clients and books are, bigger is the value. Finally, remove the extra edge in order to get the original quasi-biclique with the probability values stored in

matrix $p_{b,c,b'}$. Given the sum of the probabilities of each book b' multiplied by the profit of the book minus the production cost, you get the estimated revenue for the investment represented by edge (c, b). Thus, the same index r_{ij} defined for the TOPDMC can be calculated as defined in Eq. (1), where pp is the profit percentage estimated by the book seller and c and b are, respectively, clients i and j from the previous description.

$$r_{cb} = \sum_{b'=1}^{n} p_{b,c,b'}(d_{ij}pp - d_{ij}) \tag{1}$$

2.1 Book campaigns instance generator

Given the 3D matrix of probabilities $p(b, c, b')$, the cost of offering a book were generated at random, $d_{ij} = bc_j + dc_i$, with $bc_j \in [10, 100]$ and $dc_i \in [5, 25]$, where bc_j represents the cost of manufacturing and paying the copyright of book j while parcel dc_i represents the delivering cost of offering some book to client i. The return to the firm r_{ij} is described in Eq. (1).

The campaign operational constraints were generated following the strategy used by Nobibon et al. [5]. Thus, the minimum-quantity commitment bound O_j (the minimum amount of books that should be manufactured in the marketing campaign) was generated as a random integer selected between $|\frac{\sum_i M_i}{n}|$ and $|2\frac{\sum_i M_i}{n}|$. The budget B_j was chosen between $O_j\frac{\sum_i c_{ij}}{m}$ and $2\frac{\sum_i c_{ij}}{m}$. However, all fixed cost f_j were chosen to be 1. Campaign hurdle rate was also fixed in 15%.

A set of 75 instances was generated considering campaigns with 100 clients and the following number of available books: 10, 20, 50, 100 and 200. The rate of profit for each book was also objective of our analyzes, considering the following values: $pp = [110\%, 120\%, ..., 250\%]$. Costs were fixed for instances with the same number of books. Thus, the only changes among them are the revenue for each offer. Parameter $maxClientsPerBiclique$ was set to be number of clients divided by 3 and $maxBooksPerBiclique$ was set as half of the number of books.

3 TOPDMC optimization using a VNS algorithm

3.1 Solution representation and evaluation

A simple way to represent a solution to the TOPDMC is thought an array $R_{|C|\times|O|}$ of binary variables, in which C indicates the set of available customers able to receive offers and O, representing the set of products quoted for the

marketing campaign. If a given cell $s_{i,j}|i \in C, j \in O$ is true, the product j is going to be offered for client i.

A given solution s is evaluated by measuring the total profit of the campaign, which represents the total expected profit minus the total costs. The latter is a combination of individual clients costs plus fixed costs of each product. Thus, the goal is to maximize the evaluation function $f^{obj}(s)$ (Eq. (2)).

$$f^{obj}(s) = \sum_{i \in C} \sum_{j \in P} (r_{ij} - d_{ij}) s_{i,j} - \sum_{j \in P} f_j y_j \tag{2}$$

3.2 Neighborhood structures

To explore the search space of the TOPDMC, three Neighborhood Structures (NS), proposed by Nobibon et al. [5] and also used by Oliveira et al. [6], are considered in this study:

Swap Clients Intra – $NS^{SC^{Intra}}(s)$**:** This move swaps two clients, one active and another not offered yet, $l, m \in C$ of a given product $j \in O$, such that $s_{l,j} = s_{m,j}$ and $s_{m,j} = s_{l,j}$.

Swap Clients Inter – $NS^{SC^{Inter}}(s)$**:** Similar to the previous one, but, in this case, offers from different books $i, j \in O$ are swapped, e.g., $s_{l,i} = s_{m,j}$ and $s_{m,j} = s_{l,i}$.

Swap Products – $NS^{SP}(s)$**:** exchanges two different columns $i, j \in O$ of a given solution s, such that $y_i = 1$ and $y_j = 0$ or unlike. The now book is only added to the marketing campaign if there is, at least, O_j clients available.

3.3 GGVNS with RDM local searchs

The optimization of the remaining TOPDMC, after generating the book marketing campaign, is done by a previous designed metaheuristic algorithm [6], combining the GRASP and GVNS [2]. The GRASP construction phase uses a strategy improved from the literature and introduced by Oliveira et al. [6]. This greedy randomized solution generated returns the best solution found among $GRASPMaxIter$ generated solutions.

The GVNS exploits the search space by using the aforementioned NS. The local search was done using three Random Descent Methods (RDM), without guarantee of local optimality. A RDM is created for each neighborhood and a maximum number of random moves m_i^{RDM} are applied, for each NS i. The RDM procedure consists in randomly extracting solutions from a given NS, determining its objective function value, and moving to that solution if

improvement is found. When a better solution is found, an auxiliary counter returns to 0, otherwise, it keep going until m^{RDM} random are done without any improvement. Finally, a Variable Neighborhood Descent [4] is created with random order of the NS. The idea of using a VND based on random descents reduces the computational cost of the local search, however, consequently reducing its ability of finding local optimum solutions after its search.

4 Computational experiments and discussions

The optimization GGVNS algorithm was implemented in C++ in the framework OptFrame 2.2 [3]. The tests were carried out on a Notebook Intel i7-3537U 2.00GHz, DDR3 1.6 GHZ with 8GB of RAM, with operational system Ubuntu 14.04 and compiled by g++ 4.8.4.

4.1 GGVNS results

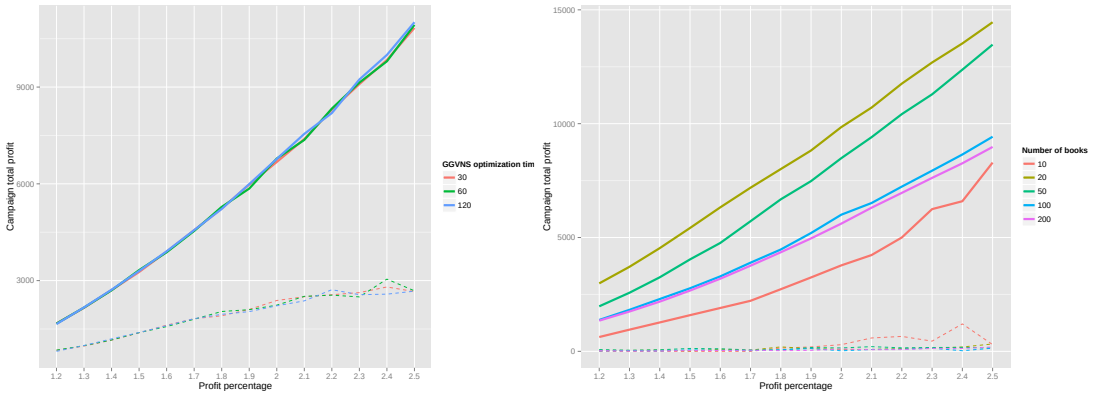
The GGVNS algorithm was applied for solving each of the 75 instances, considering executions of 30, 60 and 120 seconds. Since campaigns expected profit (HR) were fixed in 15%, and modeled as a hard constraint, some instances with $pp = 110\%$ were not feasible. The feasibility is possible in some configurations due to the fact that by offering a given book b may result in a client buying several other recommended books b'. However, for simplicity, we removed these five instances from the following analyzes.

Figure 2 shows an interaction plot regarding book profit percentage, expected campaign profit and GGVNS optimization time. The dashed line indicates the standard deviation while the thicker line shows the average total campaign profits. As can be verified, due to small size of the generated instance, the GGVNS may had reach solutions close to optimality and reported similar values for all analyzed computational times. When books profit rate are higher (more than 170%), campaign total profit seems to increase quicker. This fact can be associated with the higher number of possible profitable clients to be chosen in the marketing campaign.

5 Final considerations and possible extensions

In this brief manuscript, we introduced a novel direct marketing campaigns that deals with free book sampling. In particular, the proposed approach

[3] Available at http://sourceforge.net/projects/optframe/



(a) Book profit percentages and GGVNS optimization time

(b) Book profit percentages and number of books

Fig. 2. Interactions plots and model classification accuracy

could be also applied in the cosmetic sector, where free samples are given to costumers. A new set of instances, comprising large sets of clients and available books should be carefully generated and analyzed.

References

[1] Amor, I. B. and F. Guilbert, *Influences on free samples usage within the luxury cosmetic market*, Direct Marketing International Journal **3** (2009), pp. 67–82.

[2] Hansen, P., N. Mladenovic and J. A. M. Pérez, *Variable neighborhood search*, European Journal of Operational Research **191** (2008), pp. 593–595.

[3] Lammers, H. B., *The effect of free samples on immediate consumer purchase*, Journal of Consumer Marketing **8** (1991), pp. 31–37.

[4] Mladenovic, N. and P. Hansen, *A variable neighborhood search*, Computers and Operations Research **24** (1997), pp. 1097–1100.

[5] Nobibon, F. T., R. Leus and F. C. Spieksma, *Optimization models for targeted offers in direct marketing: Exact and heuristic algorithms*, European Journal of Operational Research **210** (2011), pp. 670 – 683.

[6] Oliveira, T. A., V. N. Coelho, M. J. F. Souza, D. L. T. Boava, F. Boava, I. M. Coelho and B. N. Coelho, *A hybrid variable neighborhood search algorithm for targeted offers in direct marketing*, ENDM **47** (2015), pp. 205 – 212.

Chapter 5

FINAL REMARKS

> "All my life through, the new sights of Nature made me rejoice like a child."
>
> Marie Curie

This thesis kept me challenged and interested in working with SC and DC themes, enlightening possibilities and applications to merge different technologies inside a city and to reinforce the citizens' importance.

After presenting the works that compose this thesis, these chapters presents the final thoughts, moreover, it discusses the possible directions, enabling potentialities and directions for future explorations and works.

5.1 Concluding thoughts

This thesis highlighted the evolution that involves the concepts around smart and digital cities, which has achieved attention both in academia, private and public sectors, whom are directing their efforts to develop the urban environment along with social participation. The bibliometrics conducted here, and potential trends around the term, showed that there is not a perfect city model, but each city adapts to its most suitable one. There are different cities across the globe and each one needs to adapt its reality and use the technology in a convenient way, both for developed and underdeveloped countries. There are different levels of technological adoption, which comes from ground level, state-of-the-art and future technology. While we can prospect about the latter two, ground level is still needed in most part of the cities in the world. Most of the SC initiatives presented in this thesis merge ICT, OR, e-governance, social interactions, blockchain, IoT, IoV with focus in better mobility, education, privacy, government, among others. This study

affirms the interdisciplinarity around the components of a city in order to cover the population needs, maintaining a good quality of life and supplying human needs. For this purpose, the city areas enabled with ICT solutions have the possibility to change the economy of the services offered to citizens, creating new opportunities for innovation.

Currently, the society have the opportunity to develop cities' urban planning with assist of digital tools, which encompasses processing power and CI based software for handling real-time information. Adequate the urban growth and the development is essential for future generations to take advantage of this advancement and to improve cities' systems even more. Valuing renewable resources, sustainable transport and less emission of pollutants is surely within the scope of technologies since complying with legislation and societal demands impacts on lower costs and higher profits in medium/long term. The computational power of modern devices can assist decision making in different spheres, from infrastructures to social participation on decisions.

This thesis boosted a search on emerging concepts such as blockchain, enabling discussions and models that may be applied in a near future. Technologies such as blockchain can guarantee a digital identity recorded inside it, as well as medical records, such as vaccines, exams. In order to generate the citizen's history anywhere he or she needs, ensuring privacy requirements at affordable costs. Its connection with governance can enable new forms of governance, where the citizens can participate more in the governmental decisions in a more transparent and reliable way.

Along this thesis we could also verify the importance of modern computational devices and the use of ICT as basins for problems resolutions. In this sense, CI concepts were approached in order to present solutions for mobility optimization problems and even optimize marketing campaigns. As it may be noticed, modern society relies on the Internet infrastructure, the populations has been dedicating its time in online activity as never before. In this sense, optimizing information that arrives to citizens in their daily activities is important for both sides, while saving time on the clients side it has the potential to increase companies' profit.

Nonetheless, one cannot be satisfied with the current understanding of the technology that surrounds us. Even with all the existing technologies and ongoing implementations, there are challenges to connect social sciences in a way to walk side with cities' development. The development of more interactive systems, easier to use and access is essential. In this regard, there is an open space for innovation that can come from startups or a transformation on the public services. Additionally, discussions surrounding technologies are a delicate topic, which I was able to experience in the academic process of this thesis. Society still struggles to show that technological advantages enables better life quality and open doors for humanity. These discussions could be verified in clashes between sustainable

or smart cities. Along the contributions presented here I tried to summarize the overall benefits and possibilities that are still to be implemented within our cities', which had the goal to motivate academia and politicians, boost industrial advances and create awareness among citizens.

In summary, this thesis addressed the use of emerging technologies in cities, pointing out challenges and discussing current limitations of the literature and real-world applications. It included discussions about the inclusion of tech in cities' services, presenting solutions that take into consideration strengthening the relationship between citizens and cities.

In particular, the precise contributions of each chapter is highlighted below:

- Chapter 2: Cities and Technologies

    1. Paper "Challenges for connecting citizens and smart cities: ICT, e-governance and blockchain":
        - Affirms the evolution of smart city relation with other areas, showing its multidisciplinary throughout technologies such as ICT, DG and blockchain to act in the mobility, industry, governance and health care, assisting the connections between them. A summary of observations is presented considering more than 120 papers from the literature is presented. An in-deep bibliometric search was conducted and supported with discussions presented by areas, as well as an update view about cities' digital transformation. It presents challenges that cities faces for transforming its infrastructure, improving visitors' experience, dealing with a more fair and transparent governance that respects citizen's privacy and promotes participation. In addition, it presents how innovation related to SC can boosts incentives from public and private sector. Reinforces the idea that citizens are the most important component inside cities.
    2. Paper "Digital Cities and Emerging Technologies":
        - This work follows on previous studies contributing with a literature review, adding precise possibilities that blockchain, smart contracts and digital democracy have on a modern city. It emphasizes the importance of these emerging technologies to provide better communications and services inside the cities. In this sense, it indicates a city can be embed with services that promote transparency, as well as presenting a discussion about modern decentralized voting systems. In addition, it presents a view about the evolution of some terms such as sustainable, digital and smart cities.

3. Paper “Citizens and Information and Communication Technologies”:
   - It’s emphasizes the potential of ICT regarding different cities’ services in order to transform them to be more connected, interconnected, participative and transparent. The scientific research reinforces the link between SC and different keywords related to social science, stating its connections and the importance of engaging citizens into social decision throughout DG and models to promote citizens participation for decision making. It presents a brief bibliometrics study indicating the eminent growth on the topic and the need to look into it with more attention.
4. Paper “Cryptocurrencies for Smart Territories: an exploratory study”
   - This exploratory study emphasizes the connections between the concept of smart territories with an interdisciplinary perspective. It shows how cryptocurrencies can play an innovative role on sustainable territorial development as complementary digital currencies. It deals with concepts such as collaborative planning, smart administration and effective policies that public institutions can do within the scope of smart cities.
5. Paper “Operational and digital challenges to connect citizens in smart cities (In Portuguese)”:
   - Presents the potential that the topic can have throughout a brief bibliometric search, indicating challenges on studying this topic. The relation between cities’ and citizens and describes the use of DG for democratic purposes in some real cases around the globe. The role of IoT is explored and discussed in the sense of sensors applied for assisting urban traffic problems. A focus is given about how to optimize citizens’ life qualify on their daily routine logistics.

- Chapter 3: Smart Cities and Operations Research

1. Paper “Mobility, Citizens, Innovation and Technology in Digital and Smart Cities”:
   - Presented a complete view about the importance of computational intelligence inside the scope of a city in order to assist transportation systems, considering more than 200 references in the analysis. This study discuss citizens mobility throughout public and private transport such as carpooling and ride-sharing, smart parking for cars and small size electric vehicles and how the paradigm

of multi-agent system can help urban traffic. In addition, it also comments about the potential of 5G and vehicle to everything in order to improve cities' integration with internet. Furthermore, it indicates how a sustainable environment for the citizens can be profitable for the society and companies throughout optimization of costs. In this sense, the concepts discussed in this study motivates a transition with responsibility, attending citizens' opinions in order to proportionate a positive economy change.

2. Papers "A multi-criteria view about judicial and legislative decision making in digital cities and societies" in English and Portuguese:
   - Analyses that different combinations of individual characteristics and experiences can result in different relevant facts in judicial and legislative process. It emphasizes an empowerment of citizens in front of disputes. The analysis considers non-nominated solutions that can be selected in order to present a solution for a given case. In summary, it indicates a new trend about how a digitalized scenario can enable citizens to participate actively on process that needs their attention on different spheres: global (nation) and local (their neighborhood or even a private condominium).
3. Paper "When CI and Decentralized Systems Effectively Meet Smart Cities and Grids":
   - Based on a major literature review, the systems proposed in this work open up a range of options about the importance of decentralized energy systems. It discuss smart grids inside the scope of SC, indicating the use of renewable energy in solar roofs, electric cars integrated in urban centers and how smart grids enables a positive transition for citizens.

- Chapter Digital Marketing 4:

1. Paper "Generic Pareto local search metaheuristic for optimization of targeted offers in a bi-objective direct marketing campaign":
   - Introduces a innovative a bi-objective cross-selling campaign for solving the NP-Hard TOPDM problem. It shows how to considers a trade-off between campaign profit and risk. The sharpe ratio was able to search for the direct marketing campaign with more pondered risk against profit. In this sense, a set of non-dominated solution provides a balance between the campaign total profit and specific group of clients that a digital marketing campaign can pick.

2. Paper "A VNS approach for book marketing campaigns generated with quasi-bicliques probabilities":
   - An adapted version of TOPDM was presented, considering the possibility of offering products expecting citizens to respond to it positively. The connection between books and clients was illustrated considering an analyzes done with quase-bicliques graphs. This work illustrates the potential that cities big data can play if managed accordingly.
3. Paper "Blockchain for Marketing Campaigns with Non-Fungible Discount Tokens":
   - Use the concept of Marketing Campaigns along with emerging technology such as blockchain in order to respect citizens privacy. It introduces a smart contract developed on the Neo Blockchain in order to manage marketing campaigns. It highlighted how marketing concepts can be used responsibly.

5.2 Future directions

There are different variations of the understanding about a smart city. As an standardization procedure, it is important to evolve towards an universal concept about smart city, that involves variations like digital city, sustainable city, intelligent city, focusing on technology itself. It is necessary to conduct discussions that sums up opinions from different areas in order to ponder technological advances and why they have been crucial for society over decades.

Payments are the core of modern society and blockchain enables it to be done in a fast secure in global manner. In daily life, it can assist the security payment of public tax and private transportation systems. Data transparency in governments and public companies is a growing demand requested by citizens and, as shown in this thesis, it has been pointed out that investments on privacy can even increase profit since citizens are looking for that. On the other hand, increasing performance of voting systems is a global need that also involves digitalization. In terms of economy, the use of secure digital tokens, which can represent ownership of a given asset, can be spread in order to assist society to collect tax and trade assets in a more sustainable manner. The introduction of monetary policies in isolated communities should be done carefully, considering the best quality of services to be offered in order to avoid dependencies with the traditional market.

A core of urban environments is also related to the access of food distribution and its quality. In order to promote decentralization of products and foods, promote the facility in the emission of certificates for products, and tracking the

production in a trusted and transparent fashion, is an eminent path that society may take.

New generation of citizens will mostly see technologies as ubiquitous, which is something that is already happening. Education needs to update its paradigms in order to match a historical overview of history. Thus, there is a need in matching history with up-to-date concepts of blockchain, ensuring trust in the way history is transmitted to the population. A first move in this direction matches the concepts of digital identity discussed in some papers approached in this thesis. By means of digital identity we are able to store facts and agreements in a modern way that blockchain is enabling.

From a ground technology perspective, there is a need to create awareness of citizens about technology. Schools should be updated and modify their schedules in order to teach digital topics, which are a reality of our current world, specially now in this time of pandemics. Challenges on how to educate citizens for the best use of technology and the connection between them and ICT needs to be considered in order to decrease the distance between them.

APPENDIX A

A.1 ADDITIONAL CONTRIBUTIONS

Each paper included here is related to a specific chapter and are described below.
Chapter 2:

- **Oliveira T.**, Coelho V.N., Tavares W., Ramalhinho H., Oliver M. (2017), Operational and digital challenges to connect citizens in smart cities (In Portuguese). In Proceedings of the XLIX Brazilian Symposium of Operational Research (SBPO), Sept. 16–19, Blumenau, Brazil. [Oliveira et al., 2017b];

Chapter 3:

- Coelho, V. N., Veloso, I. F., **Oliveira, T. A.**, & Veloso, I. (2017). A multi-criteria view about judicial and legislative decision making in digital cities and societies (In Portuguese). In Proceedings of the XLIX Brazilian Symposium of Operational Research (SBPO), September 16–19, Blumenau, Brazil. [Coelho et al., 2017b];

Chapter 4, paper under revision:

- **Oliveira, T. A.**, Coelho, V. N., Coelho, I. M., Oliver M. & Ramalhinho H. (2020). Blockchain for Marketing Campaigns with Non-Fungible Discount Tokens.

Oliveira T., Coelho V.N., Tavares W., Ramalhinho H., Oliver M. (2017), Operational and digital challenges to connect citizens in smart cities (In Portuguese). In Proceedings of the XLIX Brazilian Symposium of Operational Research (SBPO), September 16–19, Blumenau, Brazil.

Conference paper link: http://www.sbpo2017.iltc.br/pdf/170636.pdf

DESAFIOS OPERACIONAIS E DIGITAIS PARA CONECTAR CIDADÃOS EM CIDADES INTELIGENTES

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RESUMO

Distintos são os desafios para engajar os cidadãos em decisões sociais. As Tecnologias da Informação e Comunicação (TIC) possuem potencial para aprimorar tais relações, tornando os sistemas das cidades mais digitais. Este trabalho investiga a utilização dessas ferramentas nas cidades inteligentes, do inglês *Smart Cities* (SC). Com o foco em otimizar a integração entre cidadãos, apresentaremos neste trabalho problemas em aberto no contexto das áreas urbanas. Atualmente, com o advento de novas tecnologias e modelos de SC, vem emergindo uma nova onda de possibilidades para aumentar a integração e conexão entre cidadãos e cidades. Nesse âmbito, a governança digital mostra-se de fundamental importância para essa ligação, pois promove um controle cognitivo do cidadão sobre o Estado. O objetivo do trabalho é discutir, levantar pontos e sugestões em aberto perante os desafios operacionais e digitais das cidades do futuro.

PALAVRAS CHAVE. Cidades inteligentes, Cidadãos, Pesquisa Operacional.

TEL&SI – PO em Telecomunicações e Sistemas de Informações, AdP – PO na Administração Pública

ABSTRACT

There are different challenges to engage citizens in social decisions. The Information and Communication Technology (ICT) has potential to improve this relationships, making cities systems more digital. This work investigates the use of these tools in the Smart Cities (SC). With the main focus of optimizing the integration among citizens, we will present open problems within the context of urban areas. Nowadays, with the new technologies and SC models, a new wave of possibilities have been emerging for the integration and connection between citizens and cities. In this context, digital governance shows as fundamental tool for this connection, since it promotes a cognitive control of the citizen to the State. The aim of this work is to discuss, rise open points and suggestions toward the operational and digital challenges of the cities of the future.

KEYWORDS. Smart cities, Citizens, Operational Research.

TEL&SI – OR in Information & Telecommunication Systems, AdP – PO in Public Administration

1. Introdução

O contexto das cidades inteligentes, do inglês *Smart Cities* (SC), vem tomando grande foco no mundo atual. Um dos principais objetivos dessas cidades é tornar o ambiente urbano mais integrado com os cidadãos. Além disso, tomadas de decisões mais sensatas por parte dos governantes. Áreas como o transporte, a política, a governança, a educação, a transparência pública, o direito dos cidadãos, entre outras, mostram-se cada vez mais conectadas, interligadas e participativas.

De acordo com a ISO [Organization, 2014], SC é um novo conceito e modelo de cidade que envolve uma nova geração de informação e comunicação tecnológica. O objetivo chave seria facilitar o planejamento, construção e serviços inteligentes das cidades. Porém, é apontado que tal conceito [Afonso et al., 2015; Dameri e Cocchia, 2013; Ahvenniemi et al., 2017] possa estar se tornando tão cético e futurista, sendo denominado como "smart utopia" [Anthopoulos, 2017].

De acordo com o trabalho de Afonso et al. [2015], realizado nas cidades inteligentes brasileiras, o contexto das SC vem com possibilidades de mudanças significativas no perfil da democracia no país. Em especial, ressalta-se o objetivo de combinar uma nova forma de diálogo entre cidadãos e cidades. Tal como o sistema de votação digital, para petições públicas, que vem sendo proposto por Lemos [2016].

Ferramentas da Inteligência Artificial (IA) vêm sendo embutidas em dispositivos utilizados pelos cidadãos. Esse universo de dispositivos de baixo custo conectados a Internet [Zanella et al., 2014] coletam um grande volume de informações [Batty, 2013]. O ambiente interativo desses dispositivos é conhecido como Internet das Coisas, do inglês *Internet of Things* (IoT). Esse elevado número de dados podem tornar-se públicos e, até mesmo, estar ligados a tecnologias distribuídas [Silva, 2016; Lemos, 2016]. Para tratar esses dados de forma efetiva, novos sistemas vem sendo desenvolvidos, como a blockchain que será abordada posteriormente. [Andrienko et al., 2016]. Por outro lado, a Pesquisa Operacional (PO) entra neste contexto de SC para alcançarmos tomadas de decisões mais sensatas e balanceadas. As ferramentas da PO podem otimizar problemas complexos que surgem com esse mar de informações históricas e em tempo real. Plataformas para facilitar o acesso as infraestruturas da SC estão surgindo e tendo apoio da população e da academia [Lehofer et al., 2016], tal como Airbnb, Uber, Couchsurfing e outras ferramentas que conectam as pessoas com diferentes prestações de serviço. Todavia, a necessidade de adaptar regulamentações e leis é fundamental para o avanço e perpetuação dessas ferramentas. Tais sistemas já tiram proveito das informações e tendências que ocorrem nas cidades, regulamentando preços e facilitando a interação entre moradores e hóspedes.

Atualmente, nos espaços urbanos, os dados pessoais que são fornecidos para empresas tem a chance de serem repassados ou vendidos para outras empresas [Regnier et al., 2000]. Porém, se utilizados de forma sábia, tais informações podem guiar políticas públicas mais eficientes. Uma das possibilidades seriam governos mais descentralizados [Cano et al., 2014], que proporcionam maior participação local dos cidadãos. A governança digital procura melhorar a comunicação e informação do setor público, incentivando a participação da população durante processos de tomada de decisão (ex: sistemas votações mais eficientes, descentralizadas e multicritério). Desta forma, o cidadão estaria mais perto dos projetos da sua localidade, bem como, mais consciente e atualizado sobre a utilização do dinheiro público (como os portais transparência [Federal, 2017]). Esses pontos contribuem para um governo mais transparente, responsável e eficaz. Exemplos e modelos práticos estão aparecendo em distintos lugares do globo, como na vila de Panchayats, na Índia [Gokhale e Kapshe, 2016]. Tal iniciativa é também fruto do sonhado plano de Cidades Inteligentes da Índia, lançado em 2015 [Mission, 2015], com o intuito de promover iniciativas para descentralizar o governo e promover participação local. De acordo com Guimarães e de Alencar Xavier [2016], o Brasil vai caminhando para um processo de governança a partir de Estatutos que fixam a importância de princípios básicos para política urbana, como urbanismo e saneamento ambiental. Tal princípio "já define um espaço de conformação dos pilares essenciais da *smart city* em torno da inteligência ambiental e, idem para o social, mediante o planejamento sustentável das cidades, com

a participação cidadã." [Guimarães e de Alencar Xavier, 2016],(p. 1367).

A partir de análises sobre cidades inteligentes e oportunidades em aberto para melhorar o link com os cidadãos, o presente trabalho contribui com os seguintes pontos:

- Discute alguns problemas em aberto nas relações cidadão e cidades;
- Aponta desafios e tendências para o futuro das cidades inteligentes;
- Apresenta o tema da governança digital e suas contribuições para integração efetivas dos cidadãos, a partir de dispositivos IoT;
- Propõe novos modelos para conectar cidadãos e cidades:
  - Resolução de problemas de logística para distribuir telas inteligentes em pontos estratégicos das cidades;
  - Problemas de otimização e marketing para promover a cidade de acordo com o perfil de cada indivíduo que acessa as plataformas.

O trabalho está organizado como segue. A Seção 2 apresenta a contextualização dos cidadãos e cidades inteligentes. Uma abordagem sobre governança digital é dada na Seção 3, até os desafios atuais e problemas em aberto do tema abordado, Seção 4. Por fim é apresentado as considerações finais e trabalhos futuros, Seção 5.

2. Cidadãos e cidades inteligentes

Desde o surgimento do conceito de SC, termo que vem sendo trabalhado há mais de 20 anos, estudos e, consequente evolução na área continuam ocorrendo. Em 1998, Bollier propôs novas práticas políticas para melhoria do planejamento urbano e usou o termo *"smart growth"*, crescimento inteligente. Isso reafirma que o conceito de SC é originado de diferentes ideias, muitas vezes com propósitos similares. Assim como Dameri e Cocchia [2013] defendem que SC é a busca de soluções para integração ciber-física no espaço urbano.

Junto com o rápido crescimento urbano vem novos desafios, então, a SC desempenha um papel fundamental para encarar as novas barreiras, resolvendo problemas urbanos e melhorando a qualidade de vida [Yin et al., 2015]. De acordo com Sun et al. [2016], a população mundial vai duplicar até 2050. Isso fortifica e motiva o estudo de SC ao redor do mundo, com objetivo de criar espaços urbanos mais confortáveis e harmoniosos.

Para verificar o estudo nessa área no contexto brasileiro, o gráfico apresentado na Figura 1 foi gerado. Esse gráfico de tendência foi obtido com auxílio do Google Trends, uma ferramenta que permite o uso de dados a partir de 2004, comumente utilizada para avaliar a popularidade de determinadas palavras-chave. Este mecanismo processa algo como 30 milhões de buscas por semana [Batty, 2013]. Em especial, utilizamos a palavra-chave "cidade inteligente" para avaliar a tendência e interesse no contexto brasileiro. Apesar de outros países também falarem a língua portuguesa, foram encontradas buscas significantes somente no Brasil. O pico da tendência, como poder ser visto na Figura 1, está ocorrendo justamente agora, no ano de 2017. Esse crescente interesse pelo tema motiva as discussões apontadas e apresentadas durante esse presente estudo.

Com o objetivo de promover o desenvolvimento sustentável das cidades, as SC tendem a abrir novas possibilidades de inovação em várias áreas, como: saúde, bem-estar, eficiência energética e transporte [Sun et al., 2016]. As cidades do futuro mostram-se tão abrangentes que podem ser utilizadas pra proteção de cidades patrimônios culturais. As SC tem também como desafio elaborar tecnologias para proteger o patrimônio [Sun et al., 2016]. Além do patrimônio material existe o imaterial, que abrange culturas típicas de cada região (tal como folclores, danças, rituais, entre outros), que são difíceis de serem monitorados em profundidade. Tal falto ocorre também no norte do Brasil, no interior da Amazonas e em outras comunidades do Pará e Tocantins [de Souza,

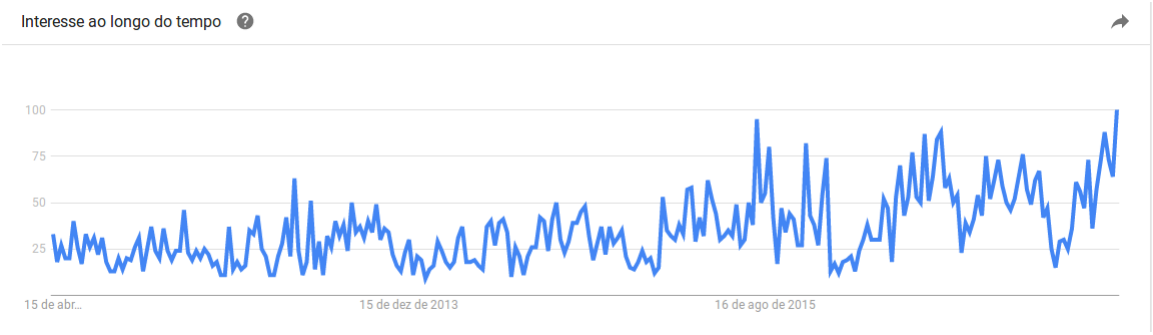

Figura 1: Pesquisa realizada pelo Google Trends com o termo: “cidades inteligentes” Trends [2017].

2015]. Medidas inteligentes deveriam promover o acesso a tecnologia de forma a preservar o patrimônio imaterial das tribos [Mesquita e Hoffmann, 2014]. Um opção seria introduzir aplicações para que os índios documentassem suas crenças e fossem promovidos pela cidades a fazer isso [Bueno, 2013].

Para apontar o contexto atual de SC na literatura, realizou-se uma pesquisa em diferentes bases de dados de referência mundial, sendo estas Web of Science, SCOPUS e IEEEXplore. Os seguintes termos foram pesquisados:

- SC (Smart city ou Smart Cities) + (Operations Research ou Operational Research);
- SC (Smart city ou Smart Cities) + Citizens;
- SC (Smart city ou Smart Cities) + (IoT ou Internet of Things);
- SC (Smart city ou Smart Cities) + (E-Governance ou E-government ou Cybergovernment ou cyber government ou cyber-government);
- SC (Smart city ou Smart Cities) + Democracy;
- SC (Smart city ou Smart Cities) + (Social Participation ou Social Science);
- SC (Smart city ou Smart Cities) + (ICT ou Information and Communication Technologies).

A Tabela 1 apresenta os resultados obtidos. É possível verificar a preocupação em mencionar as cidades inteligentes com os cidadãos e formas de governo e participação social.

	Palavras chave							
Bases de Dados	SC	SC + OR	SC + Citzens SC Citzens	SC + IoT	SC + E-Governance	SC + Democracy	SC + Social Science	SC ICT
1. Web of Science	5.522	152	667	845	83	17	228	659
2. SCOPUS	67.747	11.004	6.496	5.721	1.716	5.180	24.217	18.008
3. IEEEXplore	6.188	189	405	819	45	6	200	925

Tabela 1: Pesquisa de palavras chave abordadas no trabalho em diferentes bases de dados

Conectar cidadãos e governos locais [Mossberger et al., 2013] é um fator primordial a ser considerado no modelo de uma SC. Pensar em um modelo de cidade adaptado para o cidadão, de maneira a facilitar outros fatores, além de transporte, mobilidade, que são eventos comumente trabalhados e pesquisados, faz-se necessário. Nesse contexto, é primordial pensar em modelos de

como o cidadão pode participar efetivamente nas decisões da cidade, de maneira democrática e simples. A Seção 3 apresenta tópicos da governança digital, que podem guiar esses passos. Por outro lado, problemas de logística de localização de recursos podem também auxiliar essa tarefa (conforme será apresentado na Seção 4).

3. Governança Digital

A governança digital (GD) mostra-se de fundamental importância para atingirmos comunidades inteligentes e participativas, conforme defendido por Coe et al. [2001]. A participação democrática abre a possibilidade de um controle cognitivo do cidadão sobre o Estado, através de tecnologia da informação na transparência pública. Além disso, o conceito abarca, também, a governança estratégica na gestão e integração institucional.

A GD é fundamentada em uma governança eficiente de espaços e serviços públicos. Através dela, o cidadão pode tornar-se mais participativo e atuante nos processos de tomada de decisão em seu bairro e sua cidade [Chourabi et al., 2012]. É visível que ainda faltam ferramentas para esse tipo de tomada de decisão. Um exemplo simples pode ser visto dentro de condomínios fechados [Cruz e Pinho, 2009], onde não existe uma ferramenta mais útil para tomada de decisão e as reuniões de condomínios persistem em acontecer. Uma forma útil de sanar esse problema seria instalando equipamentos (como *tablets*) para realização de enquetes e tomadas de decisão. Esses exemplos giram em torno dos conceitos de cidades privadas, onde possuem o próprio sistema de governança [Nelson, 2005; Glasze et al., 2004].

A Internet está tornando o discurso público mais acessível assim como ocorreu à sua época com outros meios de comunicação, do telégrafo ao rádio e à televisão. Contudo, sendo um meio tecnológico ainda recente, a Internet está permitindo novas formas de organização política e de sociabilidade, bem com o aumento da capacidade de impactar politicamente indivíduos até então desinteressados [Hindman, 2008]. Com o recente avanço da Internet das Coisas (IoT), a Internet vem se tornando ainda mais frequente no dia a dia.

A IoT e as tecnologias relacionadas podem ser usadas com finalidades políticas e democráticas por uma série de agentes sociais: cidadãos, organizações governamentais, organizações da sociedade civil, partidos políticos, grupos de interesses diversos, entre outros. O que se espera, em termos de inovações democráticas, são processos de decisão compartilhados, de forma a difundir a política entre os cidadãos, em processos de discussão e deliberações, como forma e meio de ampliar a autonomia civil e as relações públicas [Colombo, 2006]. A esses processos se dá o nome de "teledemocracia", democracia digital, democracia eletrônica, governo digital, administração aberta, ciberdemocracia [Colombo, 2006], ou ainda *e*-democracia [Martí, 2008].

Para se desenvolver, a ciberdemocracia depende da sua própria prática, já que, na medida em que se desenham e se utilizam mecanismos de participação digital, surgem possibilidades de sedimentar tais práticas. Contudo, pelo que foi visto, são pequenas experiências e pouco compromisso de afetar as instituições e processos vigentes, mas é importante pensar em maiores transformações sociopolíticas. Para o alcance de objetivos, é necessário pensar inicialmente em outros tipos de Tecnologias da Informações e Comunicações (TICs) e de mecanismos como forma de romper as limitações tecnológicas e processuais [Martí, 2008].

A participação política na Internet pode dar origem a casos conhecidos, como "cidades digitais" e "governos eletrônicos ou *e-government*" [Lemos e Lévy, 2010], e até mesmo possibilidade de voto pela Internet e petições públicas. Portanto, o que está posto é uma mudança que impacta fortemente a representação política, antes vinculada quase exclusivamente aos partidos políticos [Lavalle et al., 2006]. Em tal contexto, a comunicação avança, ao criar espaços públicos autônomos e democráticos que favorecem o fluxo livre de informações e abrem possibilidades para debates de problemas sociais e formação de opinião pública crítica [Dahlberg e Siapera, 2007].

Entre as possibilidades democráticas que a Internet concede, pode haver empoderamento de partidos políticos, de ativistas e de grupos de interesse, especialmente daqueles que as mídias de massa ignoram ou denigrem. As evidências atuais indicam muitas mudanças provocadas pela

Internet no modo com que as pessoas conduzem relações socais e negócios, mas não há ainda grande impacto na participação política e na redistribuição de poder político [Margolis e Moreno-Riaño, 2009]. Por outro lado, pode ser que as práticas políticas na Internet sigam um curso semelhante ao que as práticas de negócios apresentaram quando passaram a se localizar no ambiente virtual, com fortes chances de ganhar cada vez mais espaço para as discussões e agregar cada vez mais cidadãos interessados em participar e fazer política via web [Hindman, 2008].

A Internet tem possibilitado, portanto, a criação e o desenvolvimento de uma série de ferramentas pelos governos para propiciar condições de manter uma governança eletrônica. Alguns dos marcos são: em 1994, em Minnesota (EUA), surgiu o *Minnesota e-democracy*, para dar informações sobre candidatos e suas propostas. Nos EUA, abriram-se possibilidades de cidadãos opinarem e debaterem questões políticas locais, estaduais e federais. No Reino Unido, criou-se o *UK Citizens Online Democracy*, para conceder informações e abrir espaços de debate político. Em 2003, a União Europeia lançou o *Vote for the EU you want* , um espaço de interesse supraestatal para aumentar a participação cidadã e permitir votações sobre temas de seu interesse [Colombo, 2006].

Portanto os processos atuais de democratização têm se baseado na inovação das formas de participação, que vão da incorporação de novas ferramentas e atores sociais à redefinição das identidades e afiliações, especialmente as locais [Santos e Avritzer, 2005].

As formas de participação *on-line* passaram a fazer parte do debate sobre o potencial da Internet para promover transformação no contexto democrático, possibilitando expandir o engajamento político e a esfera pública. As mudanças se dão, especialmente, pelo crescimento das comunidades virtuais e plataformas colaborativas, propiciadas, por exemplo, por *blogs* políticos e redes sociais virtuais [Shaw, 2012].

Como resultado destas e outras várias experiências ao redor do mundo, torna-se cada vez mais claro na atualidade que, quando a participação é importante e diversificada, a Internet tem potencial para se tornar uma nova e relevante arena de debates, o que pode contribuir para a propagação dos valores deliberativos em diferentes níveis de opinião e decisão. O cenário de discussão na Internet pode se fortalecer à medida que a comunicação é facilitada e surge uma variedade de temas em discussão.

Os fóruns *on-line*, por exemplo, se destacam por permitir *feedbacks* de questões específicas e por serem meios que permitem tomar conhecimento das opiniões de militantes e simpatizantes políticos [Kies, 2010]. A *blockchain* garante fóruns de informações gravadas permanentemente e de forma imutável e original, de maneira que não ocorram mudanças ou alterações [Lemos, 2016]. É possível constatar que a Internet insere-se nesse meio de forma positiva, sendo capaz de auxiliar tomadas de decisões, aprimorar os meios de comunicação e armazenar dados.

Verifica-se que existem diversos problemas e desafios em aberto, abarcando logística e também localização de recursos, sendo ferramentas que podem contribuir na resolução de tarefas. Na Seção 4 serão abordados alguns desafios atuais e problemas em aberto no contexto estudado.

4. Desafios atuais e problemas em aberto

A TIC terá um papel importante para coordenar e otimizar decisões nas cidades inteligentes. Principalmente, considerando que uma mudança na forma de governança está ocorrendo. Além disso, é possível que uma mudança de paradigma, na forma de planejar o desenvolvimento urbano, ganhe força, como descrito por Batty e traduzido neste presente trabalho:

> "(...) Eu descrevo como o crescimento do *big data* está mudando a ênfase do planejamento estratégico de longo prazo para o pensamento de curto prazo sobre como as cidades funcionam e podem ser gerenciadas, apesar da possibilidade de que durante períodos muito mais longos, este tipo de *big data* tornará uma fonte de informação a respeito de todo horizonte de tempo. (...)" Batty [2013] (p. 274).

Essa afirmativa reforça a necessidade de resolver os problemas momentâneos, que surgem a partir de quando começamos a tirar proveito do mar de dados oriundos dos dispositivos IoT. Desta forma, a TIC terá um papel importante em processar dados, comunicar com os cidadãos e auxiliar a tomada de decisão por meio de ferramentas de otimização, PO e inteligência computacional.

A Figura 2 apresenta um infográfico, elaborado pela Cisco [Clarke, 2013], para um modelo de infraestrutura de uma SC. Nos pilares das cidades situam-se os sensores interconectados, sistemas de transporte inteligente (metro, trem, drones), espaços públicos como jardins, iluminação automática e eficiente, sistema de gás, água, telecomunicação e infraestrutura para compartilhamento de energia (tal como os sistemas de geração descentralizados de pequeno porte [Coelho et al., 2016]. Além de quiosques multimídia para conectar cidadãos.

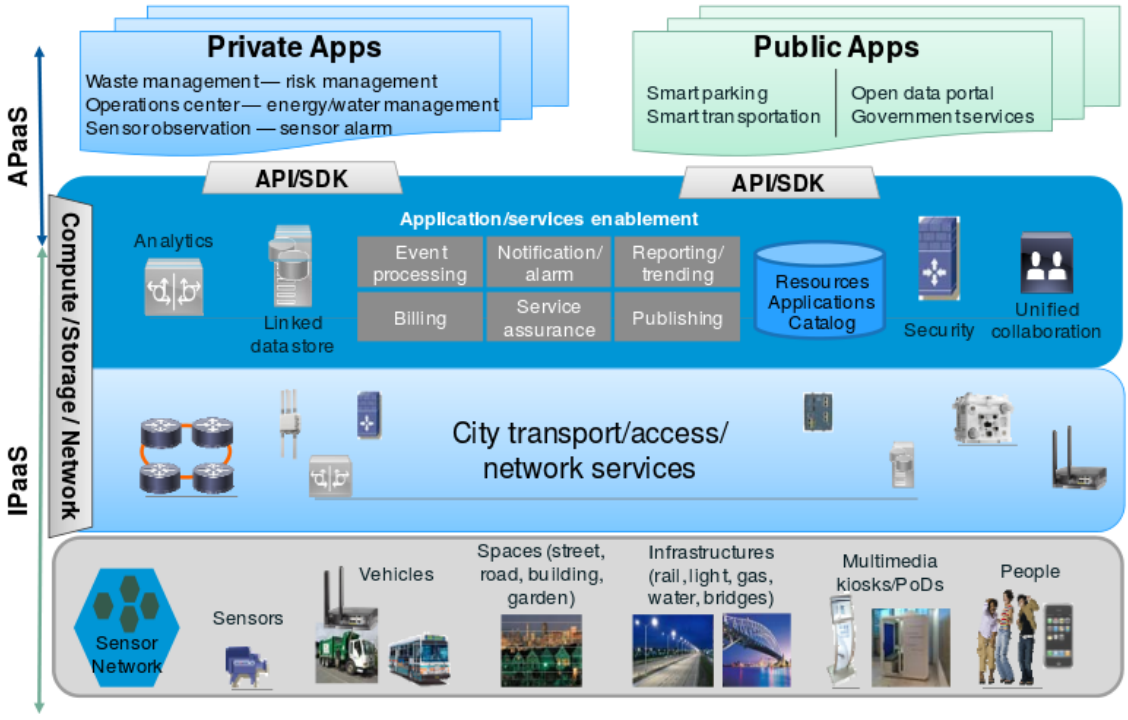

Figura 2: Modelo de cidade inteligente [Clarke, 2013].

Para otimizar o sistema de transporte na cidade utiliza-se do auxílio de sensores e dispositivos inteligentes para resolver problemas do tráfego urbano. A logística das cidades do futuro envolve a qualidade de vida dos seus habitantes em distintos pontos, tais como: qualidade do ar, ruído sonoro, tempo de acesso a pontos chave da cidades, segurança, entre outros. Deste modo, problemas de roteamento de veículos deverão considerar essas variáveis "verde", promovendo rotas mais sustentáveis e que ponderam os desejos dos cidadãos.

Para alcançar essa desejada participação social, deve-se promover formas fáceis de acesso a informação e negociação (no sentido de democracia e interação entre a população e as tomadas de decisão). A Figura 3 apresenta um projeto denominado *City 24/7 Platform Informs, Protects, Revitalizes* [Mitchel et al., 2013]. Este projeto é uma parceria entre a Cisco e a Cidade de Nova Iorque, que busca fornecer informações de programas governamentais abertos e empresas locais através de plataformas interativas.

Tais plataformas estão localizadas em pontos de ônibus, estações de trem, entradas principais de centros comerciais e instalações desportivas. Essas telas inteligentes, contam com incorporações de toque, voz, tecnologia de áudio e fornecem ofertas em tempo real. Além disso, as

Figura 3: *City 24/7 Platform Informs, Protects, Revitalizes* [Mitchel et al., 2013].

telas inteligentes podem ser acessadas através de Wifi em *smartphones* [Falaki et al., 2009], *tablets* e computadores portáteis nas proximidades. Um dos objetivos das telas inteligentes é informar as pessoas instantaneamente com informações relevantes em suas proximidades. Logo, a TIC, por meio desses dispositivos inteligentes, deverão comunicar aos cidadãos informações importantes em tempo real, como, por exemplo: horário de transporte público, postos de atendimento policial e bombeiros, eventos, parques e atividades outdoor, entre outros.

As ferramentas podem fornecer uma proteção adicional para os cidadãos, através do fornecimento de informações para órgãos competentes. Deste modo, formando uma rede de detecção, comunicação e resposta pessoal, para atender os cidadãos em casos de emergência e necessidade.

A medida que a rede for disseminando e ampliando-se com a instalação de novas *Smart* Telas, espera-se proporcionar mais valor as cidades, às empresas e os cidadãos. Determinar localizações ótimas dos telões em uma cidade é uma tarefa combinatorial, onde diversas variáveis podem ser consideradas. Então, em uma comunidade, onde instalar esses pontos de assistência? Para tal, faz-se necessário considerar o conjunto de ruas, o fluxo de cidadãos ao longo da via, a prioridade da rua em receber a tela, onde posicionar cada dispositivo. Esse problema, encaixa como um problema operacional, no qual ferramentas da PO poderiam auxiliar em tomadas de decisões mais impactantes e eficientes, além de minimizar o custo envolvido.

Além disso, determinar um conjunto compacto de informações relevantes, considerando o perfil de cada indivíduo que acessa o dispositivo, é outro problema interessante de ser tratado. Neste caso, o sistema poderia considerar preferências individuais e desejos atuais daquele que acessa a plataforma. Esse problema de marketing direto [Coelho et al., 2017] deverá oferecer os produtos adequados para cada indivíduo, prezando promover as comunidades locais, aumento da renda da cidade, aumento do bem-estar social, limpeza urbana, entre outros.

Como mencionado, as SC podem-se envolver e criar estratégias para preservação de patrimônio material e imaterial. A cidade pode promover o mapeamento de patrimônios imateriais, através de levantamentos históricos, através da divulgação de tais culturas, nos dispositivos menci-

onados, promovendo maior conhecimento por parte dos cidadãos e turistas. Espacialidades digitais para cidades inteligentes, tal como mapas interativos, foram discutidas e apoiadas por Roche [2016]. Tal inteligência urbana poderia ajudar os cidadãos a compreender suas relações com ambientes urbanos, pessoas e objetos. No âmbito do turismo, os visitantes de uma cidade poderiam ganhar menções e bonificações por visitarem pontos estratégicos marcados em um mapa iterativo.

Logo, direcionar cada cidadão para as áreas que eles mais se encaixam em uma cidade é uma tarefa que pode proporcionar distintos benefícios sociais e técnicos. Sendo que isso também pode ser aplicado a turistas. É possível ressaltar que a tecnologia vem para tornar as relações cidade e cidadão mais fáceis. De maneira a tornar essa relação mais próxima, onde o cidadão participe mais das decisões da cidade, do Estado e que ele fique mais informado sobre as notícias do governo.

5. Considerações finais e trabalhos futuros

Distintos são os desafios operacionais e digitais para conectar cidadãos em cidades inteligentes. Porém, existem elevadas opções para melhorar essa situação. Algumas delas, já em andamento, foram apontadas nesse presente estudo. Outras aplicações, exaltadas neste estudo poderão promover maior participação do cidadão para tomada de decisão de maneira mais efetiva, tanto em centros urbanos quanto em comunidades de pequeno porte.

Como trabalhos futuros sugere-se a realização de uma pesquisa de campo para analisar a opinião dos cidadãos em relação a essas conexões e participação nas decisões do Estado. Através de questionário poderia explorar a visão dos indivíduos em relação ao estado atual das cidades e tecnologias. O estudo poderia motivar investimentos e políticas em temas específicos. Como exemplo, Gaffney e Robertson [2016] analisou, por meio de entrevistas e buscas em sites, duas propostas implementadas no Rio de Janeiro, elaboradas para receber a Copa do Mundo de 2014 e o jogos Olímpicos de 2016. Da mesma forma, poderia-se aplicar distintos questionários em cidades chaves, comparando as diferentes perspectivas de seus habitantes.

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Referências

Afonso, R. A., dos Santos Brito, K., do Nascimento, C. H., Garcia, V. C., e Álvaro, A. (2015). Brazilian smart cities: using a maturity model to measure and compare inequality in cities. In *Proceedings of the 16th Annual International Conference on Digital Government Research*, p. 230–238. ACM.

Ahvenniemi, H., Huovila, A., Pinto-Seppä, I., e Airaksinen, M. (2017). What are the differences between sustainable and smart cities? *Cities*, 60:234–245.

Andrienko, G., Gunopulos, D., Ioannidis, Y., Kalogeraki, V., Katakis, I., Morik, K., e Verscheure, O. (2016). Mining urban data (part b).

Anthopoulos, L. (2017). Smart utopia vs smart reality: Learning by experience from 10 smart city cases. *Cities*, 63:128–148.

Batty, M. (2013). Big data, smart cities and city planning. *Dialogues in Human Geography*, 3(3): 274–279.

Bollier, D. (1998). *How smart growth can stop sprawl: a fledgling citizen movement expands*. Essential Books.

Bueno, C. (2013). Comunidades indígenas usam internet e redes sociais para divulgar sua cultura. *Ciência e Cultura*, 65(2):14–15.

Cano, J., Hernandez, R., e Ros, S. (2014). Distributed framework for electronic democracy in smart cities. *Computer*, 47(10):65–71.

Chourabi, H., Nam, T., Walker, S., Gil-Garcia, J. R., Mellouli, S., Nahon, K., Pardo, T. A., e Scholl, H. J. (2012). Understanding smart cities: An integrative framework. In *System Science (HICSS), 2012 45th Hawaii International Conference on*, p. 2289–2297. IEEE.

Clarke, R. Y. (2013). Smart cities and the internet of everything: The foundation for delivering next-generation citizen services. *Alexandria, VA, Tech. Rep*.

Coe, A., Paquet, G., e Roy, J. (2001). E-governance and smart communities: a social learning challenge. *Social science computer review*, 19(1):80–93.

Coelho, V. N., Coelho, I. M., Coelho, B. N., de Oliveira, G. C., Barbosa, A. C., Pereira, L., de Freitas, A., Santos, H. G., Ochi, L. S., e Guimarães, F. G. (2016). A communitarian microgrid storage planning system inside the scope of a smart city. *Applied Energy*. ISSN 0306-2619. Available online.

Coelho, V. N., Oliveira, T. A., Coelho, I. M., Coelho, B. N., Fleming, P. J., Guimarães, F. G., Ramalhinho, H., Souza, M. J., Talbi, E.-G., e Lust, T. (2017). Generic pareto local search metaheuristic for optimization of targeted offers in a bi-objective direct marketing campaign. *Computers & Operations Research*, 78:578–587.

Colombo, C. (2006). Innovación democrática y tic,¿ hacia una democracia participativa? *IDP: revista de Internet, derecho y política= revista d'Internet, dret i política*, (3):7.

Cruz, S. S. e Pinho, P. (2009). Closed condominiums as urban fragments of the contemporary city. *European Planning Studies*, 17(11):1685–1710.

Dahlberg, L. e Siapera, E. (2007). Introduction: Tracing radical democracy and the internet. In *Radical Democracy and the Internet*, p. 1–16. Springer.

Dameri, R. e Cocchia, A. (2013). Smart city and digital city: twenty years of terminology evolution. In *X Conference of the Italian Chapter of AIS, ITAIS*, p. 1–8.

de Souza, E. D. (2015). Ancestralidade e convivência, mudanças e permanências: A cultural indígena diante da era digital na aldeia kasawá-alto nhamundá. In *Anais do Fórum Internacional de Pedagogia (FIPED)*, volume 1.

Falaki, H., Govindan, R., e Estrin, D. (2009). Smart screen management on mobile phones. *Center for Embedded Network Sensing*.

Federal, G. (2017). Portal da transparência – ministério da transparência fiscalização e controladoria-geral da união. URL `http://www.portaltransparencia.gov.br/`.

Gaffney, C. e Robertson, C. (2016). Smarter than smart: Rio de janeiro's flawed emergence as a smart city. *Journal of Urban Technology*, p. 1–18.

Glasze, G., Webster, C., e Frantz, K. (2004). *Private cities: Global and local perspectives*. Routledge.

Gokhale, S. e Kapshe, C. (2016). Review of decentralised planning initiatives and urban local government functions in india. *Dynamics of Local Governments: A Comparative Study of India, UK and the USA*, p. 85.

Guimarães, P. B. V. e de Alencar Xavier, Y. M. (2016). Smart cities e direito: conceitos e parâmetros de investigação da governança urbana contemporânea/smart cities and law: concepts and research parameters for contemporary urban governance. *Revista de Direito da Cidade*, 8(4):1362–1380.

Hindman, M. (2008). *The myth of digital democracy*. Princeton University Press.

Kies, R. (2010). *Promises and Limits of Web-deliberation*. Springer.

Lavalle, A. G., Houtzager, P. P., Castello, G., et al. (2006). Representação política e organizações civis: novas instâncias de mediação e os desafios da legitimidade. *Revista brasileira de ciências sociais*, 21(60):43–66.

Lehofer, M., Heiss, M., Rogenhofer, S., Weng, C. W., Sturm, M., Rusitschka, S., e Dippl, S. (2016). Platforms for smart cities–connecting humans, infrastructure and industrial it. In *Science of Smart City Operations and Platforms Engineering (SCOPE) in partnership with Global City Teams Challenge (GCTC)(SCOPE-GCTC), 2016 1st International Workshop on*, p. 1–6. IEEE.

Lemos, A. e Lévy, P. (2010). O futuro da internet: em direção a uma ciberdemocracia/andré lemos e pierre lévy. *São Paulo: Paulus*.

Lemos, R. (2016). Using the blockchain for the public interest. URL `https://medium.com/positive-returns/using-the-blockchain-for-the-public-interest-2ed1f5114036`.

Margolis, M. e Moreno-Riaño, G. (2009). *The prospect of internet democracy*. Burlington: Ashgate Publishing Company.

Martí, J. (2008). Alguna precisión sobre las nuevas tecnologías y la democracia deliberativa.... *IDP Revista de Internet, Derecho y Política*, 6.

Mesquita, N. A. e Hoffmann, Z. (2014). Utilização das tecnologias da informação e comunicação pelo professor indígena em formação inicial. *Revista Tecné, Episteme y Didaxis: TED*. Sexto Congreso Internacional sobre Formación de Profesores de Ciencias.

Mission, S. C. (2015). Ministry of urban development, government of india (2015). URL `http://smartcities.gov.in/content/innerpage/strategy.php`.

Mitchel, S., Villa, N., StewartWeeks, M., e Lange, A. (2013). The internet of everything for cities.

Mossberger, K., Wu, Y., e Crawford, J. (2013). Connecting citizens and local governments? social media and interactivity in major us cities. *Government Information Quarterly*, 30(4):351–358.

Nelson, R. H. (2005). *Private neighborhoods and the transformation of local government*. The Urban Insitute.

Organization, I. S. (2014). TSmart cities preliminary report 2014. URL `http://www.iso.org/iso/smart\_cities\_report-jtc1.pdf`.

Regnier, B. A., Youngers, D. N., Dettinger, R. D., Spors, D. A., e Thorson, J. D. (2000). Client/server computer system having personalizable and securable views of database data. US Patent 6,134,549.

Roche, S. (2016). Geographic information science iii spatial thinking, interfaces and algorithmic urban places-toward smart cities. *Progress in Human Geography*, p. 0309132516650352.

Santos, B. d. S. e Avritzer, L. (2005). Introduction: opening up the canon of democracy. *Democratizing Democracy: Beyond the Liberal Democratic Canon, London, Verso, 2005c, pp. vii-xxxiii*.

Shaw, A. (2012). Centralized and decentralized gatekeeping in an open online collective. *Politics & Society*, 40(3):349–388.

Silva, L. (2016). Smartcities on the ethereum blockchain. URL `https://www.ethnews.com/the-future-is-now-smart-cities-on-the-ethereum-blockchain`.

Sun, Y., Song, H., Jara, A. J., e Bie, R. (2016). Internet of things and big data analytics for smart and connected communities. *IEEE Access*, 4:766–773.

Trends, G. (2017). Busca para a palavra chave "cidades inteligentes". URL `https://trends.google.com/trends/explore?q=Cidades%20Inteligentes`.

Yin, C., Xiong, Z., Chen, H., Wang, J., Cooper, D., e David, B. (2015). A literature survey on smart cities. *Science China Information Sciences*, 58(10):1–18.

Zanella, A., Bui, N., Castellani, A., Vangelista, L., e Zorzi, M. (2014). Internet of things for smart cities. *IEEE Internet of Things journal*, 1(1):22–32.

Coelho, V. N., Veloso, I. F., **Oliveira, T. A.**, & Veloso, I. (2017). A multi-criteria view about judicial and legislative decision making in digital cities and societies (In Portuguese). In Proceedings of the XLIX Brazilian Symposium of Operational Research (SBPO), September 16–19, Blumenau, Brazil.

Conference paper link: http://www.sbpo2017.iltc.br/pdf/170635.pdf

UMA VISÃO MULTICRITÉRIO PARA JULGAMENTOS EM CIDADES E SOCIEDADES INTELIGENTES

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RESUMO

A constante evolução das cidades tem impulsionado o desenvolvimento de novas ferramentas para integração entre os cidadãos. Aplicações inspiradas em técnicas da pesquisa operacional, que auxiliam a tomada de decisão, podem tornar viáveis antigos sonhos já idealizados por filósofos. Dentre esses, destacamos sistemas judiciais mais participativos, legítimos e confiáveis. Nesse âmbito, uma análise multicritério faz-se necessária, ponderando as distintas versões, crenças, culturas e, consequentes pesos e medidas desejadas por cada indivíduo. Neste trabalho, apresentamos um novo modelo para processos judiciais em cidades inteligentes. O sistema propõe a utilização de conjuntos de soluções, obtidas a partir de diferentes pesos adotados para as características sociodemográficas dos envolvidos em processos de votação. A partir de um simples estudo de caso, exaltamos as possibilidades, flexibilidade e poderio do sistema proposto. O arcabouço proposto mostra-se promissor para auxiliar a tomada de decisão em julgamentos e votações similares.

PALAVRAS CHAVE. Julgamento, Pesquisa Operacional, Cidades Inteligentes.

ADM – Apoio à Decisão Multicritério, TEL&SI – PO em Telecomunicações e Sistemas de Informações

ABSTRACT

The constant evolution of cities has driven the development of new tools for integration among citizens. Applications inspired by operational research techniques, which aid decision-making, can make viable dreams already dreamed up by philosophers. Among these, we highlight more participatory, legitimate and reliable judicial systems. In this context, a multicriteria analysis seems necessary, balancing the different versions, beliefs, cultures and consequent weights and measures desired by each citizen. In this paper, we present a new model for judicial processes in smart cities. The system proposes the use of sets of solutions, obtained from different weights adopted according to sociodemographic characteristics of those involved in the voting process. From a simple case of study, we highlight the possibilities, flexibility and potential of the proposed system. The proposed framework shows up as promising tool for assisting decision making in other similar voting scenarios.

KEYWORDS. Judgment, Operations Research, Smart Cities.

ADM – Support for Multicriteria Decision, TEL&SI – OR in Information & Telecommunication Systems

1. Introdução

A evolução das cidades para um paradigma de governança descentralizada vem sendo amplamente discutida [Coe et al., 2001]. É esperado que as Cidades Inteligentes [Almirall et al., 2016; Odendaal, 2006], do inglês *Smart Cities* (SC), possam trazer o governo mais próximo dos cidadãos [Stepan, 2000]. Ligadas por novas tecnologias da informação, as cidades inteligentes impulsionam uma forte tendência para democracias descentralizadas, como mencionado por Roberts [2004]. Descentralizar os processos de tomadas de decisão implica em repartir as decisões, estratégia que vem sendo adotadas em tecnologias baseadas em sistemas multiagentes Chalkiadakis et al. [2009]. Neste âmbito, estudos sobre governança em SC [Cano et al., 2014; Batty et al., 2012] podem garantir melhor e mais efetiva mobilidade e acesso a oportunidades, especialmente para as populações urbanas.

Da mesma forma, tais sistemas estão emergindo como importantes aliados para alcançarmos um judiciário mais independente [Shah, 1999]. Nesse contexto, ferramentas computacionais, que definem limites e pesos adequados para distintos níveis de governança são importantes recursos para tomadas de decisão mais sensatas. Iniciativas para descentralizar o governo e promover participação local vêm ocorrendo até mesmo em áreas rurais, como na vila de Panchayats, na Índia [Gokhale e Kapshe, 2016; Mission, 2015].

Comunicação bidirecional e distribuída, fundada em protocolos seguros, permanentes, serão, sem dúvida, a escolha mais sábia para as cidades do futuro. Logo, a utilização da tecnologia *Blockchain* [Silva, 2016] vem sendo estudada e cotada para distintas aplicações. Lemos [2016] vem promovendo uma ferramenta de petições públicas, para o Brasil, inspirada na *Blockchain*. Dispositivos inteligentes [Schaffers et al., 2011], capazes de obter informações e interagir com o ambiente, serão uma parte intrínseca das SC. Nesse âmbito, aplicações, modelos e novos paradigmas de interação com os cidadãos estarão em contato com grande parte dos equipamentos das SC por meio da Internet *of Things* (IoT) [Zanella et al., 2014]. Todavia, alcançar conclusões e processar a imensa quantidade de informações, extraídas e compartilhadas nas SC, é um tarefa que requer ferramentas da Pesquisa Operacional (PO), Inteligência Artificial (IA) e Otimização. Como mencionado por Gibbard-Satterthwaite [Endriss, 2007], toda regra de votação está sujeita a manipulação sempre que há mais de duas possibilidades. A tarefa de computar votos e alcançar conclusões robustas e concretas vem sendo analisada como um problema de otimização combinatória [Bartholdi III et al., 1989], de difícil resolução, que, em alguns casos, pertence à classe NP-Difícil [Mattei et al., 2013]. Existem distintas possibilidades para se chegar em acordos sociais por meio de votação, como votos por pluralidade com ou sem eliminação, acumulativos, por aprovação, eliminação em pares, entre outros [Shoham e Leyton-Brown, 2008].

No contexto brasileiro, reformas no judiciário vêm sendo discutidas pela população e por diversos trabalhos da literatura [Carvalho e Leitão, 2013; Sinhoretto, 2007; Terra et al., 2016; Brinks, 2004; Pinheiro, 1998, 2003; Melo Filho, 2003]. Por outro lado, considerando a lentidão das transformações que requerem mudanças efetivas em leis e velhos paradigmas, ressaltamos o potencial dos sistemas distribuídos e criptografados, conforme exposto por Dai [1998]. Nessa citação, menciona-se que o governo não é temporariamente "destruído", mas sim permanentemente esquecido e desnecessário. Nesse contexto, ressaltamos o papel da PO e da IA em motivar aplicações para o surgimento de sistemas e abordagens com essas capacidades e habilidades. Desta forma, sistemas mais imparciais, participativos, em que os cidadãos podem, opcionalmente, estar anônimos, poderão se tornar realidade.

Nesse breve estudo, apresentamos um sistema computacional, inspirado em técnicas da PO e otimização multiobjetivo, que poderia guiar os passos para um sistema judiciário mais participativo. O sistema aqui descrito utiliza um sistema de votação com pesos, através de critérios específicos que eliminam alternativas fora de contexto e que tentam manipular o sistema. Ao final do processo, um conjuntos de soluções não-dominadas é retornado, considerando características sociodemográficas dos envolvidos na votação. A partir de um simples estudo de caso, exaltamos

as possibilidades, flexibilidade e poderio do sistema proposto, inspirado em ferramentas de tomada de decisão multicritério [Zeleny e Cochrane, 1973]. Tal proposta, apesar de informatizar o sistema, não tira o lado "humano" do julgamento, considerando que promove-se a participação da população de forma transparente e com baixo custo. Destacam-se as seguintes contribuições do presente trabalho:

- Introdução de um novo sistema distribuído para julgamentos, no contexto das SC;
- Design de um protocolo de votação que utiliza pesos definidos para critérios sócio-demográficos do perfil de cada indivíduo.
- Apresentação de uma visão multicritério para alcançar fatos relevantes em um processo de julgamento;
- Assistência nas etapas iniciais de processos, fornecendo conclusões para auxiliar a tomada de decisão feita pelos juízes;
- Motivação de pesquisadores e governantes a investirem e desenvolverem novas tecnologias para questões sociais que implicam o julgamento de cidadãos e empresas;
- Alerta à população das possibilidades atuais que estão emergindo a partir da inserção de dispositivos inteligentes na nossa vida cotidiana, em especial, no contexto das cidades inteligentes.

O restante deste trabalho está organizado como segue. A Seção 2 apresenta o sistema proposto, bem como o arcabouço de um sistema baseado na *Blockchain* (Seção 2.3). Um estudo de caso, descrito (Seção 3.1) e solucionado (Seção 3.2), é utilizado para ilustrar uma aplicação da ferramenta proposta. Finalmente, a Seção 4 conclui o trabalho e aponta algumas possíveis extensões e trabalhos futuros.

2. Abordagem descentralizada para cidades inteligentes

Este trabalho propõe um sistema descentralizado e distribuído para processos judiciais. Um modelo simplificado é descrito na Seção 2.1. O processo de tomada de decisão, que utiliza dados de votações, é descrito na Seção 2.2. Considera-se que a coleta de dados e todo o arcabouço sejam obtidos por dispositivos IoT dentro das SC e os dados armazenados em uma *Blockchain* (conforme detalhado na Seção 2.3).

2.1. Sistema proposto

O diagrama ilustrado na Figura 1 apresenta um esquema geral do sistema proposto.

A interação dos cidadãos (que podem ser agrupados ou auto-denominados em classes distintas), promotores e outros agentes sociais poderá ser feita a partir de dispositivos inteligentes, disponíveis de forma decentralizada no contexto das cidades inteligentes. Plataformas interativas e em tempo real, embutidas nesses dispositivos, e disponíveis para os cidadãos da região em análise, serão as plataformas de entradas de dados e disseminação dos resultados. Um sistema inspirado na *Blockchain* será capaz de armazenar cada informação do processo de forma transparente e permanente.

Um coordenador central, também elegido por protocolos similares, poderá denominar um conjunto de jurados para o caso, que teriam pesos pré-definidos pelo sistema. No sistema brasileiro atual, jurados podem ser convocados em casos de crimes dolosos contra a vida [Cady et al., 2014].

Após um determinado período de levantamento dos fatos, o Indiciado poderá expor suas réplicas, bem como novos fatos. Dentre esses, o sistema será capaz de receber vídeos, fotos, documentos e qualquer outro elemento digital. Finalizado o período de fatos e réplicas, os cidadãos terão a possibilidade de votar e dar pesos para cada informação/fato daquele determinado processo.

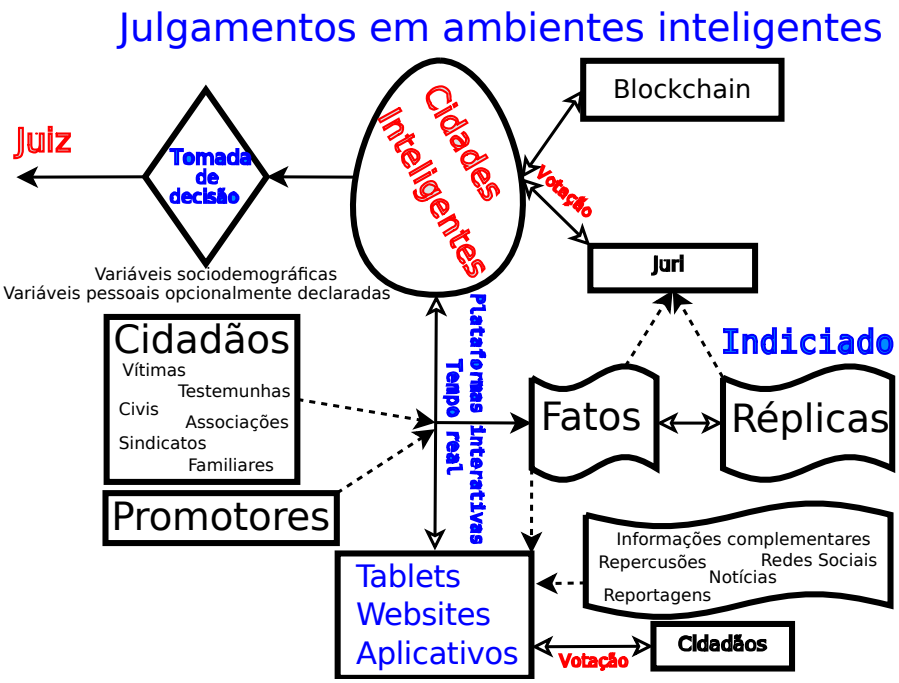

Figura 1: Ambiente distribuído para julgamento em cidades inteligentes

Além disso, um grupo de pessoas poderá participar de forma conjunta, quando legalmente registrados. Nessa mesma etapa, ressalta-se que se houver mais de um acusado, o processo pode ser dividido em várias vertentes com distintas réplicas. Por outro lado, um modelo conjunto poderia também ser considerado, abrindo a oportunidade de acessar todas as versões em um mesmo ambiente, bem como, votando em conjunto para todos os envolvidos.

Em qualquer momento do processo será possível anexar informações complementares, até mesmo de forma anônima. Tal fato já acontece nos sistema atuais, porém, por meio de interfaces paralelas. A maior vantagem de integrar essas plataformas é garantir um ambiente conjunto de acesso a informações (incluindo dados tais como aqueles do portal "Ranking dos Políticos" [Políticos, 2014]).

Finalmente, um processo de tomada de decisão retorna possíveis fatos relevantes para o processo em questão, levando em conta distintos aspectos, como:

- Informações sociodemográficos de cada cidadão que participou da votação;
- Dados pessoais, opcionalmente declarados, como: irmão da vítima, testemunha, entre outros.

2.2. Tomada de decisão multicritério

Esta seção define uma estratégia que pode ser utilizada para computar os votos de cada agente (vide Weyns et al. [2007] para mais informações sobre agentes e sistemas multiagentes) envolvido no processo de votação. Define-se a seguir uma estratégia de tomada de decisão feita com base em pesos para cada variável do perfil do cidadão, ou júri (para os casos onde for necessário); em especial, pré-definidos antes do processo se iniciar. Por exemplo, pode-se definir o seguinte conjunto de pesos para o modelo exemplificado na Figura 1: 1 ; $1,40$ e 2, respectivamente, para cidadão, vítima e júri. Além disso, cada variável do perfil dos indivíduos possui um peso específico, sendo possível analisar o impacto de certos cidadãos na decisão final da votação, por exemplo:

- Três possíveis níveis de renda com pesos $4, 2$ e 7, respectivamente, para rendas baixa, média e alta. Logo, o peso final ponderado: $0,31$; $0,15$ e $0,54$.

- Dois tipos distintos de formação (ex: Biológicas e Exatas) com pesos 7 e 5, respectivamente.
- Duas categorias de gênero com pesos 5 e 5, respectivamente.

A tomada de decisão seria feita com base nas notas dadas para cada fato ($n \in [-10, 10]$), multiplicado pelo peso do agente envolvido na votação. Desta forma, para um conjunto de fatos e possíveis réplicas $FR = \{(f_1, r_1), (f_2, r_2), \cdots, fr_i, \cdots, (f_z, r_z)\}$ cada indivíduo teria a possibilidade de dar uma nota para cada conjunto de informações fr_i. Desta forma, a nota de cada conjunto seria dado por $n^{fr_i} = \sum_{c \in C}(w_c \times n_c^{fr_i})$, sendo C o conjunto efetivo de cidadãos que deram uma nota válida para o quesito fr_i. Os pesos w_c são definidos pela média ponderada do peso de cada variável considerada de acordo com o perfil do indivíduo, ($w_c^v = [0, 10]$), onde v é cada uma das características consideradas. No caso de um grupo social (como um sindicato ou associação), a entidade poderia ter um peso específico, adotado em vista do número de associados cadastrados ou uma bonificação adicionada ao peso de cada membro efetivo que participou do processo de votação.

Para cada nota de um pacote de informações ($n^{fr_i} \mid fr_i \in FR$), valores positivos apontariam fatos a favor do réu; enquanto, por outro lado, valores negativos implicariam um fato de peso contra o acusado. Dessa forma, o sistema seria capaz de classificar os fatos que são a favor e contra.

De forma a proporcionar uma análise multicritério, propõe-se considerar diferentes combinações de pesos para cada variável sociodemográfica. Assim sendo, a partir de um conjunto de soluções, torna-se possível verificar os fatos relevantes para cada conjunto de pesos, apresentando possibilidades que variam de acordo o perfil das pessoas envolvidas na votação.

2.3. Confiabilidade e transparência a partir do uso da *Blockchain*

O levantamento de informações, durante todas etapas do processo, acontecerá por meio de uma plataforma confiável, transparente e permanente, em que a inserção de novas notícias será marcada de forma permanente em uma *Blockchain*. Blocos de notícias, marcando os autores, endereço, arquivos e tags de tempo serão minerados e incluídos em um crescente cartório digital do processo em questão. Essa ferramenta possibilitará futuras análises que relacionarão notícias e as tendência das votações sobre os fatos e réplicas alavancados nas etapas iniciais.

Além disso, ao garantir transparência e segurança no armazenando de dados do processo (em particular, promovendo abordagens distribuídas), estudos futuros poderão reanalisar os mesmos casos, porém, com novos olhares.

3. Estudo de caso

O estudo de caso, software e resultados estão disponíveis, sob licença *GNU Lesser General Public License* v3, em `git@bitbucket.org:vncoelho/judgmentssmartcities.git`.

3.1. Descrição do cenário, fatos, casos e motivação

Para exemplificar o sistema proposto, descreve-se um simples estudo de caso, composto por problemas distintos gerados com dados aleatórios.

Apresentam-se cenários fictícios compostos por 10 até 110 cidadãos, 1 até 100 fatos e 1 até 30 características analisadas (cada um com dois ou três classes). Cada possível característica do perfil de cada envolvido na votação é também definida de forma aleatória.

De forma a obter um conjunto de soluções relevantes para o processo, composto por distintas combinações de fatos relevantes, foram gerados, de forma aleatória, um grande número de combinações de pesos. Para cada característica do perfil dos envolvidos na votação, um peso entre $1, 10$ é gerado para as possíveis classes (conforme detalhado na Seção 2.2). Nos experimentos descritos na próxima Seção, foram analisadas de 1000 até 10000 combinações aleatórias desses pesos. O número total de experimentos executados foi 12000. Dentre esses, 2000 experimentos foram executados para verificar o percentual de dominância entre soluções com distintos conjuntos de fatos relevantes, sem considerar a ordem dada pelos pesos das votações.

3.2. Resultados obtidos a partir do sistema proposto

Como pode ser observado nas Figuras 2, 3 e 4, o modelo proposto foi capaz de obter um grande número de soluções relevantes. Em particular, o método possui facilidade em encontrar soluções não-dominadas quando o número de fatos considerados é alto. Para estes casos, a porcentagem de soluções não-dominadas aumenta devido ao elevado número de possibilidades de se gerar combinações de fatos relevantes (bem como, distintas ordens de relevância). Desta forma, diferentes combinações de pesos resultam, facilmente, em distintas ordens dos fatos relevantes.

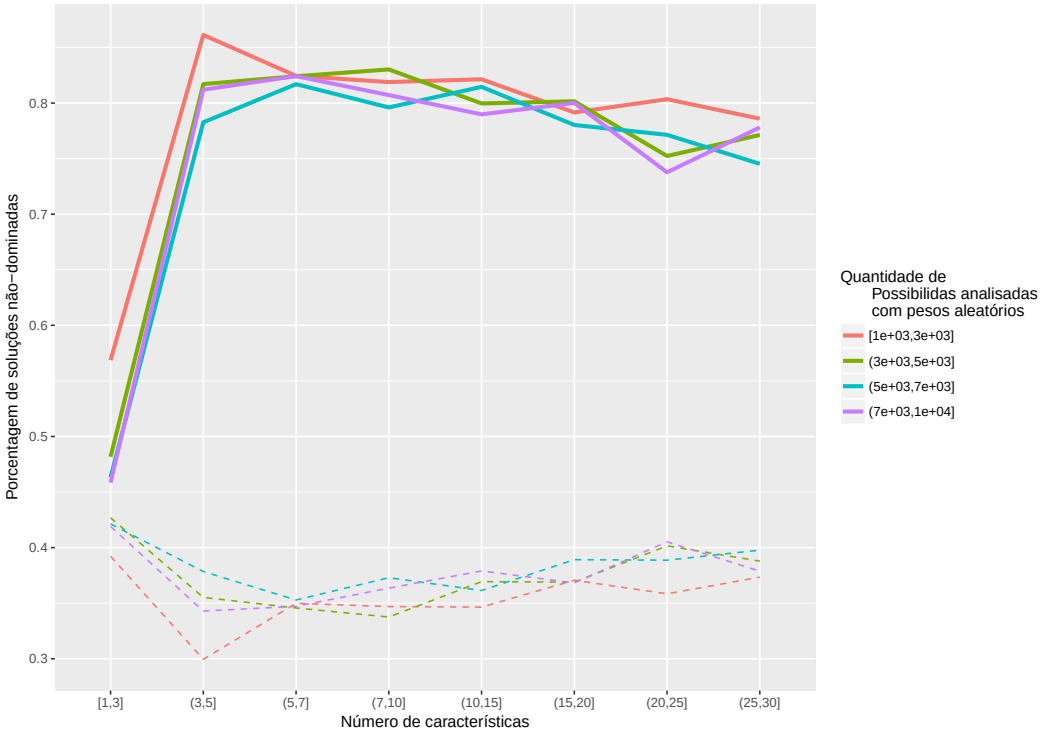

Figura 2: Gráficos de interação entre a porcentagem de soluções obtidas, a quantidade de variáveis sóciodemográficas consideradas e as combinações de pesos testadas

Considerando esse elevado número de possibilidades, ressalta-se a necessidade de novas abordagens para filtrar os fatos relevantes. Dentre essas, destaca-se a possibilidade de não considerar a ordem dos fatos relevantes como um critério de dominância. Deste modo, o gráfico apresentado na Figura 5 mostra que a porcentagem de soluções não-dominadas obtidas cai drasticamente. Além disso, os efeitos do aumento das características sócio-demográficas, Figura 6, ficam mais evidentes.

4. Considerações finais e extensões

Considerando a constante evolução das cidades para paradigmas distribuídos, um novo sistema de votação, que promove e analisa a participação de distintos cidadãos, foi proposto. Em particular, o sistema foi desenvolvido a partir de uma crescente necessidade em realizarmos julgamentos mais balanceados e com visões multicritério. O avanço e a implementação de ferramentas inspiradas nas estratégias aqui introduzidas poderá proporcionar sistemas mais participativos e "justos". Em vista do atual avanço tecnológico, espera-se que sistemas descentralizados e transparentes sejam o núcleo das tomadas de decisões em sociedades inteligentes.

O modelo aqui proposto poderia ser embarcado em diversos dispositivos já em posse dos cidadãos ou, até mesmo, instalados em pontos estratégicos das cidades. Trabalhos futuros poderiam considerar a influência de notícias e dados externos, relacionando a publicação e divulgação dessas informações com as tendências de votação (durante o período em que o processo estiver em aberto).

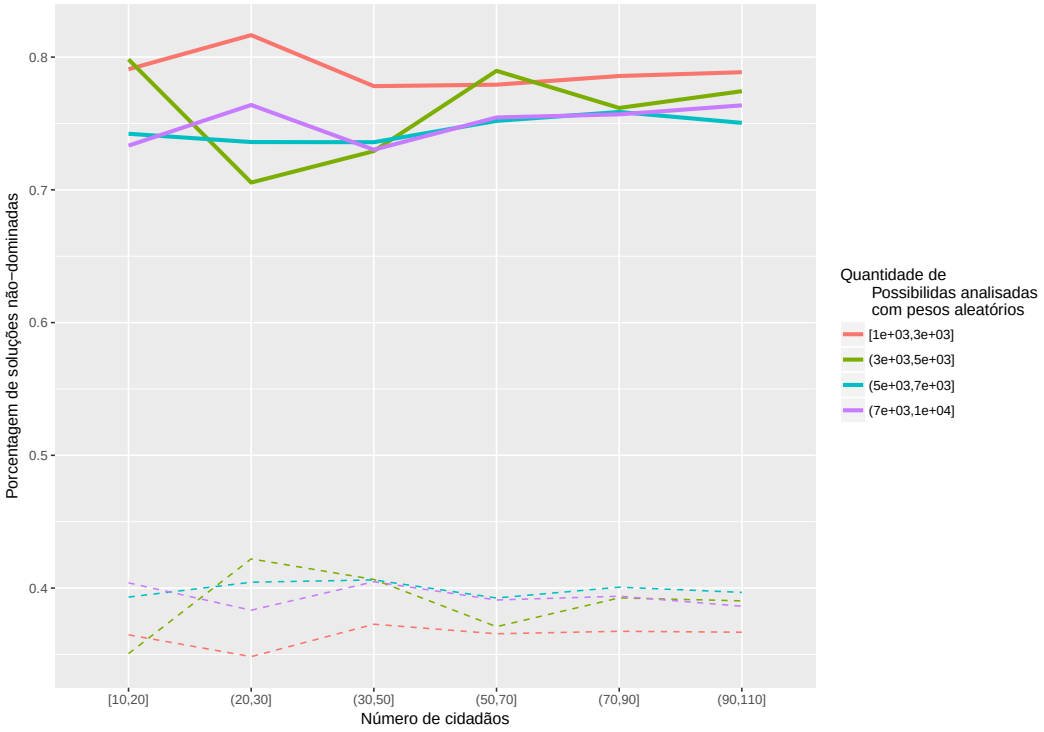

Figura 3: Relação entre a porcentagem de soluções não-dominadas e o número de cidadãos envolvidos no processo de votação

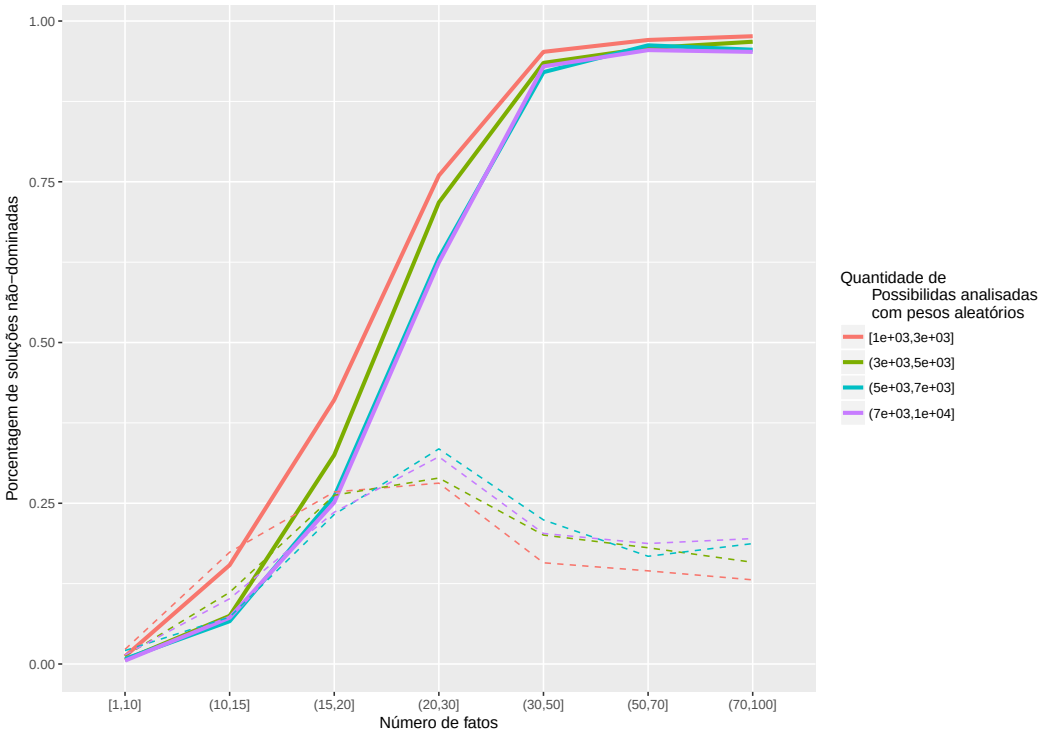

Figura 4: Crescimento da taxa de soluções não-dominadas com o aumento no número de fatos considerados

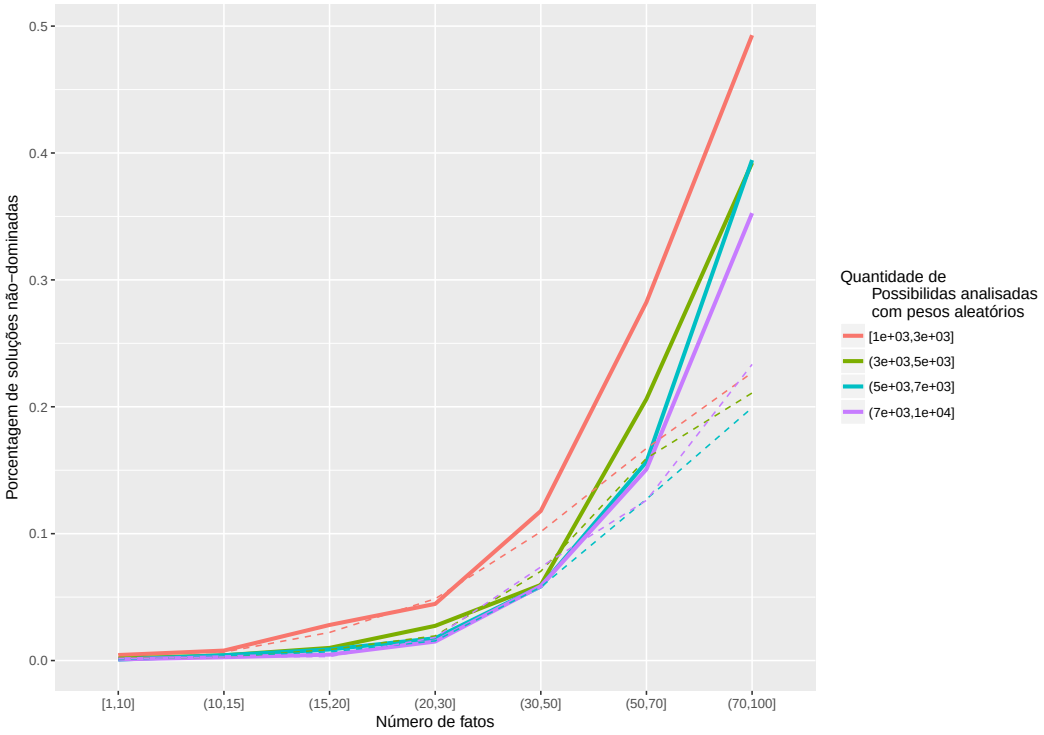

Figura 5: Crescimento do número de soluções não-dominadas com o aumento no número de fatos considerados, considerando dominantes apenas soluções com fatos distintos relevantes

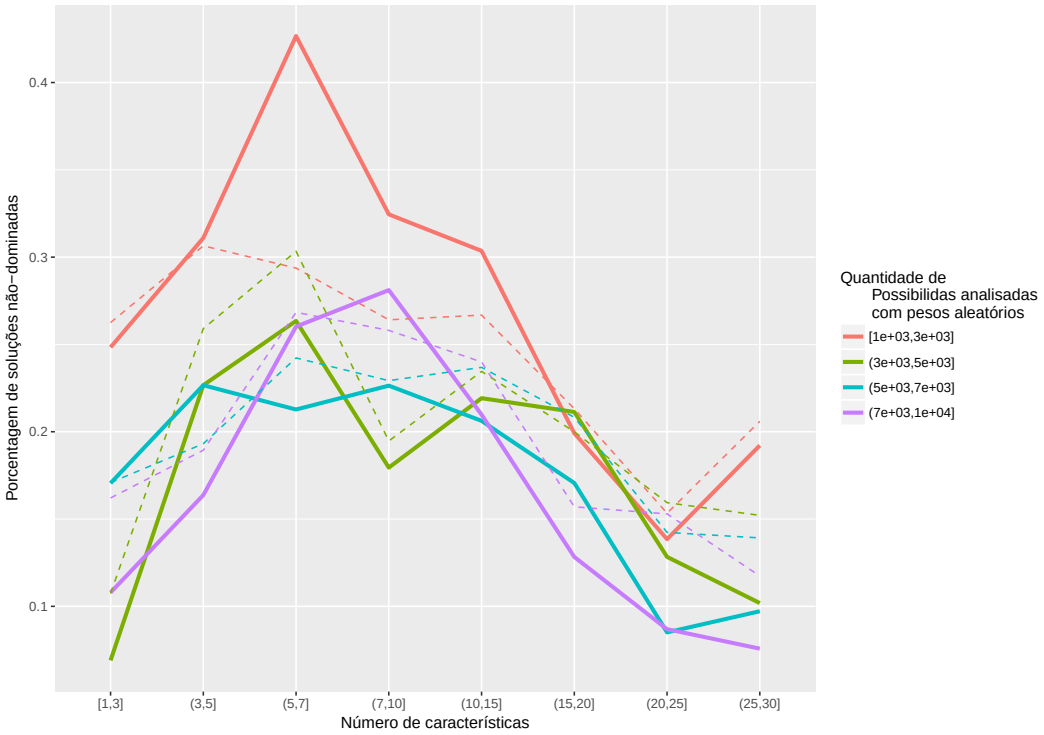

Figura 6: Aumento do número de variáveis por indivíduo e impacto na porcentagem de soluções não-dominadas

Uma etapa adicional no processo poderia considerar a exclusão de todos aqueles que alavancaram fatos com peso final ≥ 0, visto que esses fatos são a favor do réu ou não possuem relevância (tais fatos podem, também, ter recebido essas notas por serem fatos possivelmente manipulados). Buscar pesos específicos que originam determinadas conclusões é outra estratégia que poderia ser adotada para compreender os anseios dos envolvidos na votação. Logo, algoritmos metaheurísticos cooperativos poderiam buscar soluções que aumentam e otimizam o conjunto de soluções não-dominadas, ampliando o leque e poderio das possíveis conclusões.

Como possibilidade futura, ressalta-se a utilização de técnicas clássicas de tomada de decisão, como PROMETHEE II e Analytic Hierarchy Process (AHP) [Dağdeviren, 2008], que são normalmente utilizadas para encontrar alternativas satisfatórias entre as possíveis soluções. Desta forma, poderia-se considerar os pesos já fornecidos pelos envolvidos na votação e utilizar a técnica AHP para definir os pontos mais relevantes do processo.

A proposta desse trabalho motiva o avanço de novos protocolos de votação, não somente para problemas desafiadores das nossas cidades, mas, também, para o âmbito de novos protocolos de negociação para sistemas multiagentes. Aproximar a evolução das técnicas computacionais com os dispositivos utilizados pelos cidadãos, prezando imparcialidade e transparência, poderá impactar em avanços significativos para a qualidade de vida das sociedades do futuro.

Agradecimentos

Os autores são gratos a todas as pessoas que pagaram, foram presas e sofreram punições por fatos mal acurados, por motivarem e inspirarem o desenvolvimento do sistema aqui proposto.

Referências

Almirall, E., Wareham, J., Ratti, C., Conesa, P., Bria, F., Gaviria, A., e Edmondson, A. (2016). Smart cities at the crossroads: New tensions in city transformation. *California Management Review*, 59(1):141–152.

Bartholdi III, J. J., Tovey, C. A., e Trick, M. A. (1989). The computational difficulty of manipulating an election. *Social Choice and Welfare*, 6(3):227–241.

Batty, M., Axhausen, K. W., Giannotti, F., Pozdnoukhov, A., Bazzani, A., Wachowicz, M., Ouzounis, G., e Portugali, Y. (2012). Smart cities of the future. *The European Physical Journal Special Topics*, 214(1):481–518. ISSN 1951-6401.

Brinks, D. (2004). Judicial reform and independence in brazil and argentina: the beginning of a new millennium. *Tex. Int'l LJ*, 40:595.

Cady, M. C., Yin, C. W., de Araújo Filho, J. P., Vasconcelos, A., Nascimento, J. M. B., de Jesus Cerqueira, A., Olívia, M., Setúbal, S., Junior, O. P. S., e Pessoa, R. B. (2014). Tribunal do júri: uma breve reflexão. *Jus Navigandi. Teresina. a*, 9.

Cano, J., Hernandez, R., e Ros, S. (2014). Distributed framework for electronic democracy in smart cities. *Computer*, 47(10):65–71.

Carvalho, E. e Leitão, N. (2013). The power of judges: The supreme court and the institutional design of the national council of justice [o poder dos juízes: Supremo tribunal federal e o desenho institucional do conselho nacional de justiça]. *Revista de Sociologia e Politica*, 21(45):13–27.

Chalkiadakis, G., Elkind, E., Polukarov, M., e Jennings, N. R. (2009). The price of democracy in coalition formation. In *Proceedings of The 8th International Conference on Autonomous Agents and Multiagent Systems - Volume 1*, AAMAS '09, p. 401–408, Richland, SC. International Foundation for Autonomous Agents and Multiagent Systems. ISBN 978-0-9817381-6-1. URL http://dl.acm.org/citation.cfm?id=1558013.1558068.

Coe, A., Paquet, G., e Roy, J. (2001). E-governance and smart communities: a social learning challenge. *Social science computer review*, 19(1):80–93.

Dağdeviren, M. (2008). Decision making in equipment selection: an integrated approach with ahp and promethee. *Journal of Intelligent Manufacturing*, 19(4):397–406.

Dai, W. (1998). b-money. URL http://www.weidai.com/bmoney.txt.

Endriss, U. (2007). Vote manipulation in the presence of multiple sincere ballots. In *Proceedings of the 11th conference on Theoretical aspects of rationality and knowledge*, p. 125–134. ACM.

Gokhale, S. e Kapshe, C. (2016). Review of decentralised planning initiatives and urban local government functions in india. *Dynamics of Local Governments: A Comparative Study of India, UK and the USA*, p. 85–Local Government Quarterly.

Lemos, R. (2016). Using the blockchain for the public interest. URL https://medium.com/positive-returns/using-the-blockchain-for-the-public-interest-2ed1f5114036.

Mattei, N., Narodytska, N., e Walsh, T. (2013). How hard is it to control an election by breaking ties? *arXiv preprint arXiv:1304.6174*.

Melo Filho, H. C. (2003). A reforma do poder judiciário brasileiro. In *Seminário sobre a Reforma do Judiciário*.

Mission, S. C. (2015). Ministry of urban development, government of india (2015). URL http://smartcities.gov.in/content/innerpage/strategy.php.

Odendaal, N. (2006). Towards the digital city in south africa: Issues and constraints. *Journal of Urban Technology*, 13(3):29–48.

Pinheiro, A. C. (1998). A reforma do judiciário: uma análise econômica. *Trabalho apresentado no Seminário Internacional "Sociedade e a Reforma do Estado", realizado em São Paulo de*, 26.

Pinheiro, A. C. (2003). Judiciário, reforma e economia: a visão dos magistrados. *Instituto de Pesquisa Econômica Aplicada (Ipea)*. URL http://hdl.handle.net/11058/2900.

Políticos, R. (2014). Ranking políticos. URL http://www.politicos.org.br/.

Roberts, N. (2004). Public deliberation in an age of direct citizen participation. *The American review of public administration*, 34(4):315–353.

Schaffers, H., Komninos, N., Pallot, M., Trousse, B., Nilsson, M., e Oliveira, A. (2011). Smart cities and the future internet: Towards cooperation frameworks for open innovation. In *The Future Internet Assembly*, p. 431–446. Springer.

Shah, A. (1999). Balance, accountability, and responsiveness: lessons about decentralization. *World Bank Policy Research Working*, (2021). URL https://ssrn.com/abstract=623937.

Shoham, Y. e Leyton-Brown, K. (2008). *Multiagent systems: Algorithmic, game-theoretic, and logical foundations*, chapter Aggregating Preferences: Social Choice. Cambridge University Press.

Silva, L. (2016). Smartcities on the ethereum blockchain. URL https://www.ethnews.com/the-future-is-now-smart-cities-on-the-ethereum-blockchain.

Sinhoretto, J. (2007). Law reform (case study) [reforma da justiça (estudo de caso)]. *Tempo Social*, 19(2):157–177. URL `https://www.scopus.com/inward/record.uri?eid=2-s2.0-39549114252&partnerID=40&md5=fb08f7c06a1890b1042ad363152fde46`.

Stepan, A. (2000). Brazil's decentralized federalism: Bringing government closer to the citizens? *Daedalus*, 129(2):145–169.

Terra, L., Ventura, C., Medeiros, M., e Passador, J. (2016). Strategies for the distribution of power in brazil: A proposal from the perspective of the viable system model (VSM). *Systems Research and Behavioral Science*, 33(2):224–234.

Weyns, D., Omicini, A., e Odell, J. (2007). Environment as a first class abstraction in multiagent systems. *Autonomous Agents and Multi-Agent Systems*, 14(1):5–30. ISSN 1387-2532.

Zanella, A., Bui, N., Castellani, A., Vangelista, L., e Zorzi, M. (2014). Internet of things for smart cities. *IEEE Internet of Things journal*, 1(1):22–32.

Zeleny, M. e Cochrane, J. L. (1973). *Multiple criteria decision making*. University of South Carolina Press.

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MDPI

Article

Blockchain for Marketing Campaigns with Non-Fungible Discount Tokens

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Abstract: Blockchain has the potential of promoting transparency and trust when used as public chains and some hybrid permissioned environments. The problem of selecting clients in Direct Marketing campaigns is a NP-hard combinatorial optimization that involves the selection of clients that will receive some offer. This problem can cover a wide range of possible applications and has been solved by different sectors of the industry, focusing on attending citizens according to their wishes. This paper has the goal of highlighting the use of the solutions obtained from the resolution of this problem in a decentralized social application, defined as Smart Campaigns. For achieving that, we show the potential of a metaheuristic based algorithm and how the obtained solutions could interact with a Smart Contract deployed on the NEO Blockchain Ecosystem.

Keywords: NEO Blockchain, Direct Marketing, Metaheuristics, Smart Contracts, Non-Fungible Token

Key Contribution: The breakthroughs or highlights of the manuscript. Authors can write one or two sentences to describe the most important part of the paper.

1. Introduction

Blockchain is providing opportunity for innovative solutions that promotes interaction of users and service providers in a peer-to-peer fashion. A great functionality that Blockchains allows us is to use Smart Contracts (SC) [1]. In addition, these systems provide users control to their data and, for the first in history, Internet-of-Value (IoV). By connecting these points, we propose a system, so-called Smart Campaigns, that provides optimized data to the Blockchain and incentives users based on discount vouchers.

The concept of smart and digital cities [2,3] involves innovative integration between governance, industry and society. In this sense, while data should be stored in a private and safe manner (using state-of-the-art technologies such as Blockchain [4–7]) we should threat and use it in the most efficient manner. In addition, smart cities concepts promotes the use of more transparent solutions by service providers, which is in connection with citizens' gaining control of their choices.

The Targeted Offer Problem in Direct Marketing Campaign (TOPDMC) is a special case of Direct Marketing (DM) campaigns, where operational research techniques can be used to optimize the profit from the values generated by response models. When solving a variant of the TOPDMC, we seek to

select the most profitable set of customers for offering products in DM campaigns. Generally speaking, the main goal is to find an appropriate set of clients to receive one or more offers, maximizing campaign profits while respecting operational requirements.

The amount of data that has been stored by private and public applications is reaching impressive numbers. Such big data can be used in a search for increasing enterprises profit, but can also work in favor of users when transparency and privacy are key components of the system. Blockchain has this potential and this paper reinforces how it can be a bridge for real-time interaction between industry and clients.

The main contributions of this current paper are:

- Applies Blockchain for a more transparent scenario of DM campaigns;
- Designs a Smart Contract for managing discount vouchers forged in the form of Non-Fungible Tokens (NFT) [8];
- Promotes users flexibility in registering to a system and using its benefits in a transparent manner;
- Uses a state-of-the-art nature inspired metaheuristic algorithm for solving the TOPDMC NP-Hard problem.

The remainder of this paper is organized as follow:

Section 2 describes the variant of the TOPDMC problem dealt within the scope of this study, and also details the Neighborhood Guided Evolution Strategies (NGES) metaheuristic used for solving the NP-Hard problem. Section 3 details the SC designed and introduced in this research for managing the Direct Marketing campaigns system. Results of the metaheuristic proposed for solving the problem are presented at Section 4 along with a real example of how the SC can be deployed and its interaction with NEO Blockchain. Finally, Section 5 draws some final consideration and future research directions.

2. The Targeted Offer Problem in Direct Marketing Campaign with Discount Tokens

The TOPDMC can be defined as a set of clients $C = [c_1, c_2, ..., c_m]$ and a set of offers $O = [o_1, o_2, ..., o_n]$, a cost d_{ij} and profit r_{ij} are associated to each offer, $j \in O$, targeted to a specific customer $i \in C$. Those estimated parameters d_{ij} and r_{ij} are usually obtained from marketing response models. For each client $i \in C$, there is a number of maximum offers M_i, which indicates the maximum number of useful offers that a client i may receive. For each product offer $j \in O$, there is a strict minimum number of products O_j^{min} that should be offered during the campaign, a minimum expected profit R (also known as hurdle rate), an available budget B_j and, finally, a fixed cost f_j if the product j is chosen to be disseminated in that campaign. Different mathematical formulation, including a depth-first branch-and-price heuristic, can be found in the work of [9].

In the Blockchain context, we consider each offer O as a discount voucher, B_j as the maximum budget for discounts, the fixed cost f_j is consider as the cost of sending this voucher in the Blockchain as a Transaction. Each voucher is generated in a SC in a form of a NFT, the cost d_{ij} is the discount given in a voucher of a given product j to client i, while the profit r_{ij} is the probability that client i will really use the voucher to buy the product. Both of them are generated based on the profile of the registered costumers. Both values are generated before-hand and given to the optimizer to solve this variant of the TOPDMC.

2.1. Representation and evaluation of a solution

A trivial way to represent a solution to the TOPDMC is a binary array $R_{|C|\times|O|}$, where C indicates the set of available customers willing to receive discount voucher and O, representing the set of possible product discount vouchers quoted for the marketing campaign. If a given cell $s_{i,j}|i \in C, j \in O$ is equal to true, the NFT j will be transfered to the client i on the Blockchain.

A given solution s is evaluated by measuring the total profit of the campaign, which represents the total expected profit of the set of active clients minus the total costs. The latter is a combination of individual clients discounts plus fixed costs of blockchain transactions.

2.2. Solving the TOPDMC with the Neighborhood Guided Evolution Strategies

The NGES is a Less is More metaheuristic introduced by [10] and recently described in details at [11]. In the first reference, the method was applied to three different combinatorial optimization problems, which were able to show the convergence of the method and present competitive results with the literature. The latter applies the method in some well-known Vehicle Routing Neighborhood Structures, discussing its convergence and concepts of local and global optimality.

To explore the search space of the TOPDMC, three Neighborhood Structures (NS) proposed by [9] and also used by [12,13], were used here. It should be noticed that the initial greedy randomized solution generator, described in [12], generates only feasible solutions. The following NS are used in order to walk through the feasible search space.

- Swap Clients Intra – $NS^{SC^{Intra}}(s)$: This movement consists in swapping two positions, $l, m \in C$ of a given discount voucher offer $j \in O$, such that $s_{l,j} = s_{m,j}$ and $s_{m,j} = s_{l,j}$.
- Swap Clients Inter – $NS^{SC^{Inter}}(s)$: Similar to the movement $N^{TC-Intra}(s)$, but in this case, different vouchers $i, j \in O$ are swapped, e.g., $s_{l,i} = s_{m,j}$ and $s_{m,j} = s_{l,i}$.
- Swap Vouchers – $NS^{SV}(s)$: exchanges two different columns $i, j \in O$ of a given solution s, such that $y_i = 1$ and $y_j = 0$ or unlike. Thus, a group of product discount vouchers which is not being used in the campaign ($y_j = 0$) can be now part of the active set of discount vouchers to be used during the campaign.

2.2.1. Local search

The local search was done following a Random Descent Method (RDM) without guarantee of local optimality. A RDM is created for each neighborhood and m^{RDM} random moves are applied. Thus, RDM consists in extracting randomly a solution from a given NS and determining its objective function value, Finally, a Variable Neighborhood Descent (VND) is created in the following order: $NS^{SC^{Intra}}(s)$, $NS^{SC^{Inter}}(s)$ and $NS^{SV}(s)$.

The idea of using a VND based on random descents reduces the computational cost of the local search, however, reducing its ability of ensuring local optimum solutions after its search.

3. NEO-VM C# Smart Contract

A draft of the Smart Contract, designed for being compiled and deployed on the NEO Blockchain, has been done in order to illustrate the possible system that can manage such DM campaigns, with key functions detailed in Figure 1.

A general owner of the SC can manage campaigns, registering them with associated maximum budget and respective campaign owner. The owner of each campaign is able to register discount vouchers, protected by public key based cryptography and with some specific details. A function for transferring the voucher to a given client allows the campaign manager to specify the discount to be given, without worrying about limits, since SC automatically checks maximum budget at every operation. Client can redeem their discount voucher by signing a transaction informing the voucher hash. All voucher owned by clients can be listed by RPC calls to the nodes of the network. In addition, synchronized nodes can track changes and create specific design off-chain datasets. Some characteristics of the components involved in this smart contract can be seen at the UML class diagram detailed in Figure 1.

4. Results on solving the TOPDMC and Smart Contract deployment

4.1. TOPDMC Benchmark results

Some computational experiments were carried on a Intel Core i7-3537U CPU (2.00GHz), with 4GB of RAM, operating system Ubuntu 18.04.

```
public class DirectMarketingCampaigns : Framework.SmartContract
{
    public static readonly byte[] SCOwner =
    "AK2nJJpJr6o664CWJKi1QRXjqeic2zRp8y".ToScriptHash();
    // Owner of the Smart Contract, able to Register Campaings
    private static readonly byte[] PREFIX_REGISTERED_CAMPAIGNS =
    "REGISTERED_CAMPAIGNS".AsByteArray();
    private static readonly byte[] PREFIX_REGISTERED_CAMPAIGNS_BUDGET =
    "REGISTERED_CAMPAIGNS_BUDGET".AsByteArray();
    private static readonly byte[] PREFIX_REGISTERED_CAMPAIGNS_OWNER =
    "REGISTERED_CAMPAIGNS_OWNER".AsByteArray();
    public static Object Main(string operation, params object[] args)
    {
            if (operation == "registerCampaign") return RegisterCampaign(args);
            // Register a campaign with: a maximun budget and campaignOwner
            if (operation == "getRegisteredCampaigns") return GetRegisteredCampaigns(args);
            // Get number of registered campaigns
            if (operation == "getCampaignBudget") return GetCampaignBudget(args);
            // Get campaign total budget
            if (operation == "getCampaignOwner") return GetCampaignOwner(args);
            // Get campaign owner
            if (operation == "registerDiscountVoucher") return RegisterDiscountVoucher(args);
            // Register discount voucher: campaignID, number of vouchers,
            //maximum discount value, discount product, expire date (block)
            if (operation == "getProductNumberOfVouchers") return GetProductNumberOfVouchers(args);
            // get total number of vouchers: campaignID, voucherID
            if (operation == "transferVoucher") return TransferVoucher(args);
            // transferVoucher: campaignID, voucherID, addressOfNewOwner, discountID
            if (operation == "getVoucherValue") return GetVoucherValue(args);
            // get voucher value: campaignID, voucherID, clientID
            if (operation == "registerClients") return RegisterClients(args);
            // Register the profile of a client that is willing to participate in the DM campaigns
            if (operation == "getClientVouchers") return GetClientVouchers(args);
            // List vouchers owned by a client: clientID
            if (operation == "setClientLimit") return setClientLimit(args);
            // Set maximum number of voucher to be received for a given client
            if (operation == "changeOwner") return ChangeSCOwner(args);
            // Change Smart Contract Owner
            if (operation == "changeCampaignOwner") return ChangeCampaignOwner(args);
            // Change Campaign Owner: campaignID
            if (operation == "redeemVoucher") return RedeemVoucher(args);
            // Clients uses the voucher: voucherHash
            return true;
    }

    public static BigInteger RegisterCampaign(object[] args)
    {
        if (!Runtime.CheckWitness(SCOwner))
        {
            Runtime.Notify("You are not allowed for this operation...:");
            return 0;
        }
        if (args.Length != 2) return 0;
        byte[] cOwner = (byte[])args[0]; BigInteger maxBudget = (BigInteger)args[1];
        BigInteger registeredCampaigns = ++Storage.Get(PREFIX_REGISTERED_CAMPAIGNS).AsBigInteger();
        Storage.Put(PREFIX_REGISTERED_CAMPAIGNS,registeredCampaigns);
        byte[] idAsByteArray = registeredCampaigns.AsByteArray();
        Storage.Put(idAsByteArray.Concat(PREFIX_REGISTERED_CAMPAIGNS_OWNER),cOwner);
        Storage.Put(idAsByteArray.Concat(PREFIX_REGISTERED_CAMPAIGNS_BUDGET),maxBudget);
        return registeredCampaigns;
    }
```

Algorithm 1. Smart Contract code in C# - Available at https://github.com/ThaysOliveira/Non-Fungible_Discount_Tokens

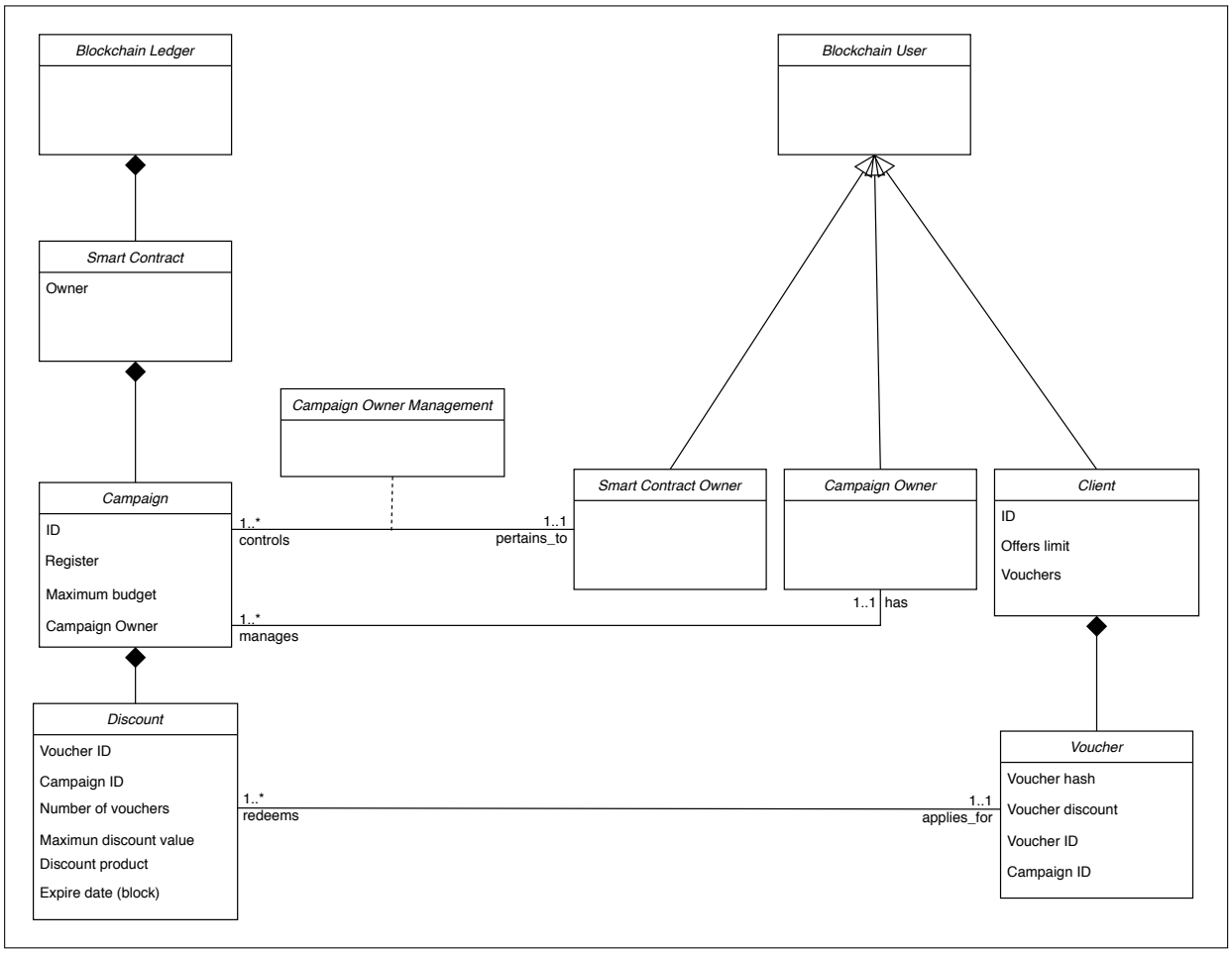


Figure 1. Direct Marketing Campaigns Smart Contract UML class diagram.

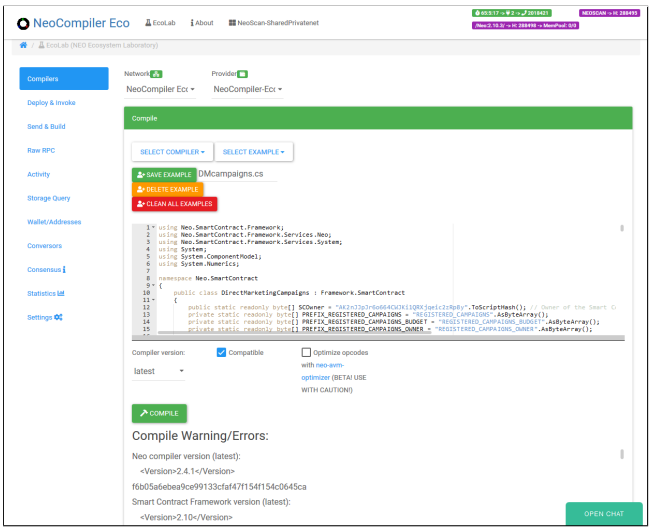
To validate the proposal, a set of 54 large instances, with 10000 clients, generated by [9], was used. This group is divided in three subgroups, composed with different number of product offers: 5, 10 and 15 with 18 instances each, which differ with respect to the profits, costs and boundaries of the operational constraints. Eight variants of the algorithm were created, varying the number of used NS and local search phase, as well as size of parents and offspring population. A single run was performed for each of the 54 large instances with 1200 seconds of executions, following the computational time reported by a Tabu Search algorithm [9]. Errors were measure by the $gap_i^n = \frac{f_i^* - f_i^n}{f_i^*}$, in which f_i^* is the the best known result for each benchmark problem and f_i^n the value obtained by each algorithm.

The results were consistent with previous achievements of other papers and methods used from the literature, indicating the efficiency of the solution for finding solutions close the optimal ones, with average GAPS of 12.9%, 12.3% and 12.5% for the instance sets L-5, L-10 and L-15, respectively. It was verified that the use of the RDM intensification phase also improved the quality of final solutions. By analysing the probabilities of applying each NS structure it was noticed that by self-adapting the probability of $NS^{SC^{Inter}}(s)$ there was a high concentration of improvements. This fact reinforces the idea that NGES is able to increase its perturbation level in order to search for new solutions.

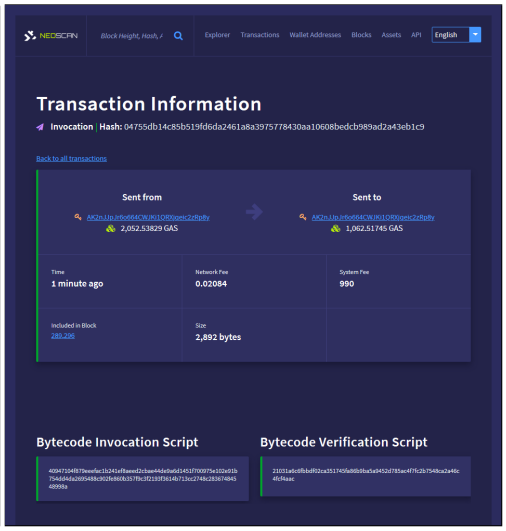
In this sense, this methodology has the potential for assisting the selection of the most promising set of clients for receiving the discount tokens managed by the SC.

4.2. Smart Contract Test with NeoCompiler.io

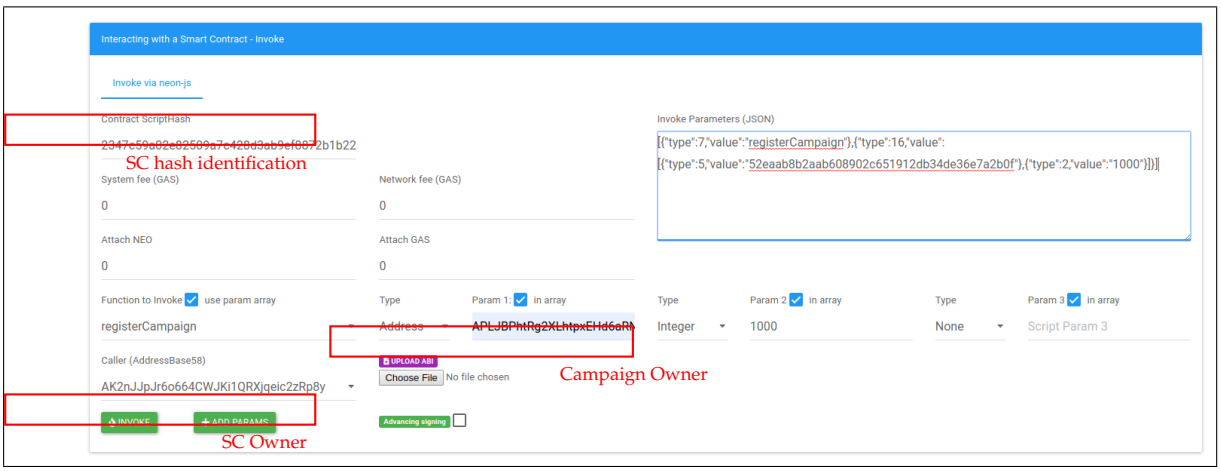
In order to test the proposed design of the Smart Contract, the C# code was deployed on a shared private net, as displayed in Figure 2.



(a) Compiling the Smart Contract with the NeoCompiler Eco (https://neocompiler.io).



(b) Deployment transaction of the SC 2347c59a02e82509a7c428d3ab9ef8872b1b22fb.



(c) Registering a campaign for the owner with public key APLJBPhtRg2XLhtpxEHd6aRNL7YSLGH2ZL and maximum budget equals to 1000.

Figure 2. Compiling the SC with an online compiler in order to test it on a Private Net.

The first step is to compile the code into NEO Virtual Machine (neo-vm) native language, Figure 2a, which generates a set of opcodes interpreted by the neo-vm (available at https://github.com/neo-project/neo-vm). The contract was deployed with success, under hash number 2347*c*59*a*02*e*82509*a*7*c*428*d*3*ab*9*ef*8872*b*1*b*22*fb*, as can be seen in Figure 2b, and different campaigns were registered, as in the example depicted in the parameters of Figure 2c which registers the owner with public key *APLJBPhtRg*2*XLhtpxEHd*6*aRNL*7*YSLGH*2*ZL* and maximum budget equals to 1000. Cryptographic protection of the owner of the deployed campaign worked as expected, as well as the functions for managing who is able to register vouchers just after the smart contract owner registered each specific campaign, limited by a maximum budget.

The proof of concept was considered to be valid and the proposed features worked as defined in the specification and suggested design.

5. Final considerations and extensions

This paper introduced a new class of Direct Marketing Campaigns, so-called Smart Campaigns, which connects the resolution of a NP-Hard problem with the decentralized process that Blockchain provides. A well-known problem, the TOPDMC, was conceptually adjusted to a scenario where clients were registered in the Blockchain and received discount voucher created as NFT.

Industry can take profit of the proposed system by entering in the world of IoV, tokenizing its campaigns by simple following the flow of the SC introduced in this study. The use of SC can not only be an effective and low-cost way of offering vouchers but also a path for a more transparent and trustable way for promoting smart economy.

Designing efficient DM campaigns can be profitable and beneficial for several real-world applications, from the industry sector to modern cities governance strategies under discussions on the scope of smart cities. For this reason, this problem was detailed and solved with a state-of-the-art algorithm, the NGES. Besides being a metaheuristic with few components, NGES posses a simple framework easy to be reproduced and replicated.

As future research directions we plan to extend the SC functionalities with more privacy settings, as well as creating novel models for incentives and interact with users.

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Abbreviations

The following abbreviations are used in this manuscript:

DM	Direct Marketing
IoV	Internet-of-Value
NEO-VM	NEO Virtual Machine
NFT	Non-Fungible Tokens
NGES	Neighborhood Guided Evolution Strategies
NS	Neighborhood Structures
RDM	Random Descent Method
SC	SmartContracts
TOPDMC	Targeted Offer Problem in Direct Marketing Campaign
VND	Variable Neighborhood Descent

References

1. Hongfei, Da and Zhang, Erik. NEO: A distributed network for the Smart Economy. Technical report, NEO Foundation, 2015.
2. Oliveira, T.A.; Coelho, V.N.; Ramalhinho, H.; Oliver, M. Digital Cities and Emerging Technologies. In *Smart and Digital Cities*; Springer, 2019; pp. 197–207.
3. Dameri, R.P.; Cocchia, A. Smart city and digital city: twenty years of terminology evolution. X Conference of the Italian Chapter of AIS, ITAIS, 2013, pp. 1–8. doi:10.1016/j.sbspro.2014.11.137.
4. Marchionni, P. Next Generation Government Service Bus: The Blockchain Landscape. Technical report, Agenzia per l'Italia Digitale (AgID), 2018. Version 1.2.
5. Blockchains for Social Good.
6. Timsit, T.L..L.C..K. Blockchain and the GDPR. Technical report, Consensys AG, 2018. Thematic report.
7. Portier, C.C..M.L..B. Blockchain and GDPR: How blockchain could address five areas associated with GDPR compliance. Technical report, IBM, 2018.

8. Regner, F.; Urbach, N.; Schweizer, A. NFTs in Practice–Non-Fungible Tokens as Core Component of a Blockchain-based Event Ticketing Application. 40th International Conference on Information Systems (ICIS 2019), 2019.
9. Nobibon, F.T.; Leus, R.; Spieksma, F.C. Optimization models for targeted offers in direct marketing: Exact and heuristic algorithms. *European Journal of Operational Research* **2011**, *210*, 670 – 683. doi:10.1016/j.ejor.2010.10.019.
10. Coelho, V.N.; Coelho, I.M.; Souza, M.J.F.; Oliveira, T.A.; Cota, L.P.; Haddad, M.N.; Mladenovic, N.; Silva, R.C.P.; Guimarães, F.G. Hybrid Self-Adaptive Evolution Strategies Guided by Neighborhood Structures for Combinatorial Optimization Problems. *Evolutionary Computation* **2016**, *24*, 637–666. doi:10.1162/EVCO_a_00187.
11. Nazário Coelho, V.; Machado Coelho, I.; Mladenović, N.; Ramalhinho, H.; Ochi, L.S.; Guimarães, F.G.; Souza, M.J.F. Less Is More: The Neighborhood Guided Evolution Strategies Convergence on Some Classic Neighborhood Operators. Variable Neighborhood Search; Sifaleras, A.; Salhi, S.; Brimberg, J., Eds.; Springer International Publishing: Cham, 2019; pp. 77–88.
12. Oliveira, T.A.; Coelho, V.N.; Souza, M.J.F.; Boava, D.L.T.; Boava, F.; Coelho, I.M.; Coelho, B.N. A hybrid variable neighborhood search algorithm for targeted offers in direct marketing. *Electronic Notes in Discrete Mathematics* **2015**, *47*, 205 – 212. The 3rd International Conference on Variable Neighborhood Search (VNS'14), doi:http://dx.doi.org/10.1016/j.endm.2014.11.027.
13. Oliveira, T.A.; Coelho, V.N.; Ramalhinho, H.; Souza, M.J.; Coelho, B.N.; Rezende, D.C.; Coelho, I.M. A VNS approach for book marketing campaigns generated with quasi-bicliques probabilities. *Electronic Notes in Discrete Mathematics* **2017**, *58*, 15 – 22. 4th International Conference on Variable Neighborhood Search, doi:https://doi.org/10.1016/j.endm.2017.03.003.

Sample Availability: Samples of the compounds ..... are available from the authors.

Bibliography

[Afonso et al., 2015] Afonso, R. A., dos Santos Brito, K., do Nascimento, C. H., Garcia, V. C., and Álvaro, A. (2015). Brazilian smart cities: using a maturity model to measure and compare inequality in cities. In *Proceedings of the 16th Annual International Conference on Digital Government Research*, pages 230–238. ACM.

[Ahvenniemi et al., 2017] Ahvenniemi, H., Huovila, A., Pinto-Seppä, I., and Airaksinen, M. (2017). What are the differences between sustainable and smart cities? *Cities*, 60:234–245.

[Barbosa et al., 2019] Barbosa, A. C., Moraes, T. M., Tesima, D. T., Pontes, R. C., de Sá Motta Lima, A., and Azevedo, B. Z. (2019). *Smart Planning: Tools, Concepts, and Approaches for a Sustainable Digital Transformation*, pages 221–236. Springer International Publishing.

[Barbosa et al., 2018] Barbosa, A. C., Oliveira, T. A., and Coelho, V. N. (2018). Cryptocurrencies for smart territories: an exploratory study. In *2018 International Joint Conference on Neural Networks (IJCNN)*, pages 1–8.

[Bonetto et al., 2020] Bonetto, R., Sychev, I., Zhdanenko, O., Abdelkader, A., and Fitzek, F. H. (2020). Smart grids for smarter cities. In *2020 IEEE 17th Annual Consumer Communications & Networking Conference (CCNC)*, pages 1–2. IEEE.

[Chun et al., 2010] Chun, S., Shulmanb, S., Sandovalc, R., and Hovyd, E. (2010). Government 2.0: Making connections between citizens, data and government. *Information Polity*, 15:1–9.

[Coe et al., 2001] Coe, A., Paquet, G., and Roy, J. (2001). E-governance and smart communities: a social learning challenge. *Social science computer review*, 19(1):80–93.

[Coelho et al., 2019a] Coelho, V. N., Coelho, I. M., Oliveira, T. A., and Ochi, L. S. (2019a). *Introduction*, pages 1–5. Springer International Publishing.

[Coelho et al., 2019b] Coelho, V. N., Coelho, I. M., Oliveira, T. A., and Ochi, L. S., editors (2019b). *Smart and Digital Cities: From Computational Intelligence to Applied Social Sciences*. Springer International Publishing.

[Coelho et al., 2019c] Coelho, V. N., Gabrich, Y. B., Oliveira, T. A., Ochi, L. S., Barbosa, A. C., and Coelho, I. M. (2019c). When ci and decentralized systems effectively meet smart cities and grids. In *Smart and Digital Cities*, pages 239–249. Springer.

[Coelho et al., 2017a] Coelho, V. N., Oliveira, T. A., Coelho, I. M., Coelho, B. N., Fleming, P. J., Guimarães, F. G., Ramalhinho, H., Souza, M. J., Talbi, E.-G., and Lust, T. (2017a). Generic pareto local search metaheuristic for optimization of targeted offers in a bi-objective direct marketing campaign. *Computers & Operations Research*, 78:578–587.

[Coelho et al., 2019d] Coelho, V. N., Oliveira, T. A., Figueiredo, I. V. O., Souza, M. J. F., and Veloso, I. (2019d). *A Multicriteria View About Judicial and Legislative Decision Making in Digital Cities and Societies*, pages 209–220. Springer International Publishing.

[Coelho et al., 2017b] Coelho, V. N., Veloso, I. F. O., Oliveira, T. A., Coelho, V. N., Veloso, I., Veloso, V. M., Souza, M. J. F., and Filho, A. F. S. (2017b). A multi-criteria view about judicial and legislative decision making in digital cities and societies (in portuguese). In *Proceedings of the XLIX Annual Brazilian Symposium on Operational Research*, page 3979 a 3989.

[Cohen, 1995] Cohen, J. E. (1995). Population growth and earth's human carrying capacity. *Science*, 269(5222):341–346.

[Creating.City, 2020] Creating.City (2020). Proceedings organized by the creating.city team. https://creating.city/proceedings/, accessed on 2020-03-23.

[DóAuria et al., 2014] DóAuria, A., Tregua, M., and Bifulco, F. (2014). From digital city to smart city: different perspectives overlapping or misinterpreted? In *Proceedings of the GVGlobal Virtual Conference*. EDIS - Publishing Institution of the University of Zilina.

[Gendreau et al., 2019] Gendreau, M., Potvin, J.-Y., et al. (2019). *Handbook of metaheuristics*, volume 272. Springer.

[Gibson et al., 1992] Gibson, D. V., Kozmetsky, G., and Smilor, R. W. (1992). *The technopolis phenomenon: Smart cities, fast systems, global networks*. Rowman & Littlefield.

[Jünger et al., 2009] Jünger, M., Liebling, T. M., Naddef, D., Nemhauser, G. L., Pulleyblank, W. R., Reinelt, G., Rinaldi, G., and Wolsey, L. A. (2009). *50 Years of integer programming 1958-2008: From the early years to the state-of-the-art*. Springer Science & Business Media.

[Lourenço et al., 2003] Lourenço, H. R., Martin, O. C., and Stützle, T. (2003). *Iterated Local Search*, pages 320–353. Springer US, Boston, MA.

[Oliveira et al., 2018] Oliveira, T. A., Barbosa, A. C., Ramalhinho, H., and Oliver, M. (2018). Citizens and information and communication technologies. In *2018 International Joint Conference on Neural Networks (IJCNN)*, pages 1–7.

[Oliveira et al., 2019] Oliveira, T. A., Coelho, V. N., Ramalhinho, H., and Oliver, M. (2019). *Digital Cities and Emerging Technologies*, pages 197–207. Springer International Publishing.

[Oliveira et al., 2017a] Oliveira, T. A., Coelho, V. N., Ramalhinho, H., Souza, M. J., Coelho, B. N., Rezende, D. C., and Coelho, I. M. (2017a). A VNS approach for book marketing campaigns generated with quasi-bicliques probabilities. *Electronic Notes in Discrete Mathematics*, 58:15 – 22. 4th International Conference on Variable Neighborhood Search.

[Oliveira et al., 2017b] Oliveira, T. A., Coelho, V. N., Tavares, W., Ramalhinho, H., and Oliver, M. (2017b). Operational and digital challenges to connect citizens in smart cities (in portuguese). In *Proceedings of the XLIX Annual Brazilian Symposium on Operational Research*, pages 3819–3830.

[Oliveira et al., 2020a] Oliveira, T. A., Gabrich, Y. B., Ramalhinho, H., Oliver, M., Cohen, M. W., Ochi, L. S. S., Gueye, S., Protti, F., Pinto, A. A. A., Ferreira, D. V. M. V. M., Coelho, I. M. M., and Coelho, V. N. N. (2020a). Mobility, citizens, innovation and technology in digital and smart cities. *Future Internet*, 12(2):22.

[Oliveira et al., 2020b] Oliveira, T. A., Ramalhinho, H., and Oliver, M. (2020b). Challenges for connecting citizens and smart cities: ICT, e-governance and blockchain. *Sustainability*, 12(7):21.

[Raschke et al., 2018] Raschke, P., Küpper, A., Drozd, O., and Kirrane, S. (2018). *Designing a GDPR-Compliant and Usable Privacy Dashboard*, pages 221–236. Springer International Publishing, Cham.