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Review

Smart Cities and Transportation: Reviewing the Scientific Character of the Theories

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Abstract: The concept "smart city" nowadays designates a plethora of things. The multiple meanings associated with the smart city, and its imperfect synonym the "robotic city", continue to provide a topic of debate. In this paper we aim to present an epistemologically grounded review of articles focused on the concept of "smart city" and its correlatives. The goal of this article is to ascertain whether the scientific character of the theories employed in such articles is discussed and/or ascertained. For this purpose, we used Popper's method of falsification: a theory's scientific character is determined by its falsifiability and eventual falsification. Papers from the literature were extracted using the PRISMA method, and 15 studies were assessed as eligible for analysis. Most conclusions and results expounded in the articles reviewed that claim to be scientific are arguably based on the unsound logic of verification and confirmation rather than falsification. This has the detrimental effect of reducing to the category of logically false universal instantiations the majority of conclusions about (a) smart city services and infrastructures, (b) intelligent transportation systems and (c) blockchain/Internet of Things.

Keywords: smart city; transportation; epistemology

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1. Introduction

A smart city is a concept in urban planning and development, describing a city that is equipped with "smart" technology to make life easier and more efficient. It is used alongside several terms (like "intelligent city", "information city", "digital city", "ubiquitous city", "smart community", "creative city", "sustainable city", or "robotic city") [1–3] and it has no clear and singular cross-disciplinary definition [4]. Its various aspects outline the idea that a smart city contributes to a sustainable and safe way of life for all its citizens [5,6] and has minimal negative impact on the environment. Many "smart" technologies can be applied in a wide range of areas, from infrastructure to transportation, healthcare, energy generation, etc.

We approach the concept of "smart city", which can be divided into two major concepts: smart transportation and smart environment. Smart transportation (ST) encompasses the electronic infrastructure, mechanical infrastructure, artificial intelligence systems, traffic signal control systems and management strategies aiming to transform transportation into a green, sustainable system, i.e., an intelligent transportation system (ITS). Meanwhile, the concept of "smart environment" means that transportation is linked with the environment. In this case, the transportation system and the environment are managed in a sustainable manner. It can be stated that a transportation system can be transformed into "smart transportation" by using information and communication technology (ICT) [7].

There are several smart environment systems that can be used for intelligent transportation. Smart parking systems is one example [8]. A smart parking system is an intelligent system that provides users with real-time information about traffic flow around the area. This is used for automatically guiding drivers to parking lots in accordance with vehicle movement information, including the type of vehicle, the location of the vehicle, and the specific parking lot [9]. Furthermore, intelligent transportation systems (ITSs) involve using communications technology to monitor and manage a wide range of factors that affect traffic flow, and to reduce traffic congestion [10].

Smart environment systems represent features that are shared in the reviewed literature between the concept of "smart city" and its imperfect synonym: "robotic city". The latter concept was coined in the early 1960s by Herron with his "Walking City", which was an idea of a "metropolis consisting of a series of mobile structures that could move about on enormous telescopic steel legs" [11]. Notably, his idealized framework is interesting because it entails several aspects that are relevant for "smart" and "robotic" cities alike: various levels of automation, autonomous regeneration, juxtaposed mobility, management of environmental issues, flexible infrastructure, etc.

The robotic city is predicated on a series of notions that may alter not only people's daily activities, but may also lead to "a paradigm shift in architectural discipline as it will face the needs to evolve and inform the technological and philosophical pursuits that lead to the possibility of such a machinic 'field condition' in the urban fabric of the near future" [12]. Goyal's text foreshadows multiple features that can be reviewed to gain insights into the inner workings of a robotic city. Its architecture is based upon the Internet of Robotic Things (IoRT) in a similar manner to the way in which the "smart city" is grounded upon the Internet of Things (IoT) infrastructure. In fact, IoRT can be considered a particular type of IoT, because it has been described in some sources as being based on "Cloud Robotics and the IoT infrastructure" [3].

IoRT has received several descriptions and definitions. In our review we use the definition suggested by Ray: "A global infrastructure for the information society enabling advanced robotic services by interconnecting robotic things based on, existing and evolving, interoperable information and communication technologies where cloud computing, cloud storage, and other existing Internet technologies are centered around the benefits of the converged cloud infrastructure and shared services that allows robots to take benefit from the powerful computational, storage, and communications resources of modern data centres attached with the clouds, while removing overheads for maintenance and updates and enhancing independence on the custom cloud based middleware platforms, entailing additional power requirements which may reduce the operating duration and constrain robot mobility by covering cloud data transfer rates to offload tasks without hard real time requirements" [13]. This definition entails a multi-layered architecture of IoRT, a feature mentioned in the articles that consider robotic cities. This feature is the cause of their scalability [3].

Basically, robotic cities have a multi-layered architecture that includes:

(1) The hardware/robotic things layer comprising real hardware, such as robots, vehicles, sensors, smart phones, defence equipment, home appliances etc. This is considered to be the lowest layer.
(2) The network layer containing at least one type of network connectivity option: 3G, 4G. It can encompass a plethora of short-range communication technologies, such as WiFi, Bluetooth, Broad Band Global Area Network etc. Furthermore, this layer includes medium- to long-range technologies such as Z-Wave, ZigBee, and Low Power Wide Area Network (LoRA), in order to attain smooth conduct of information transmission.
(3) The Internet Layer, which is the nexus of the communication channels in a robotic city and, at a more abstract level, in the IoRT architecture. In order to increase efficiency, IoT protocols are generally added selectively: MQTT, CoAP, XMPP, IPv6, UDP etc. These protocols perform multiple tasks oriented towards the effective transfer of data, providing privacy for datagram protocols, lightweight local automation [3,13].
(4) The infrastructure layer, which is actually a cluster of five "compositions": Robotic platform support, M2M2A cloud platform, IoT Business Cloud Services, Big Data services and IoT Cloud Robotics Infrastructures. The first composition offers spe-

cific service technologies, the second provides solutions based on sensor-generated visualized information services. These services are interlinked and make up complex chains of actions/reactions that are performed by robots [13]. IoT Business Cloud Services are abstracted for representing IoT specific business. This "composition" has multiple functions, such as easing e-commerce operations, optimization, resource definition, management of external ecosystems, etc. IoT Cloud Robotics Infrastructures is the "composition" that is included only for enabling services such as image and video processing, location identification, communication control, robotic behaviour scenarios etc.

(5) The application layer, which is the highest and most abstracted layer of the IoRT architecture. It spreads the user experience by exploring the applications that can be completed using robotics, such as infrastructure maintenance, health care, meteorological disasters, various types of shows, etc. [13].

This multi-layered architecture is based on the thesis that every resident of a robotic city is not only a consumer, but also a producer of data, actuation, policy and knowledge.

In this paper we review articles dedicated to the concept of smart cities from an epistemological standpoint, in order to ascertain whether the theories used in the papers are scientific. For this purpose, we have used the most rigorous method of determining the scientific character of a theory: Popper's falsification method. The goal of this article is to ascertain whether the scientific character of the theories employed in such articles is discussed and/or ascertained. In our review, we noticed the fact that concepts such as "smart cities", "robotic cities", "IoRT", "IoT", "intelligent transportation systems" have been the subject of empirical research grounded on particular theories, in order to obtain confirmation of specific theories. These can be considered superficial endeavours because the assertions that emerge from this kind of confirmation are based on circumstantial evidence. Furthermore, without a well-grounded method of establishing the scientific character of the various theories used in the research process, the value of the studies presented are arguable at best. Therefore, we reviewed these studies using Popper's method of falsification: a theory's scientific character is determined by its falsifiability and eventual falsification.

The paper is relevant in the field since it approaches the development of the theory of creating smart cities, and is aimed at eliminating the gap in this topic, which requires identifying the possibility of falsification of works.

The rest of the paper is organised as follows: Section 2 some presents some theoretical aspects of the concepts used in the article. Section 3 shows the methodology used in this work. Section 4 presents preliminary considerations, results, and discussion about the scientific character of the theories identified in the selected studies. Finally, the conclusions drawn are presented in Section 5.

2. Theoretical Foundation

2.1. Smart City Definition

The concept "smart city" nowadays designates an umbrella concept. To paraphrase Sterling, most of the things it stands for are ensnared in banality [14]. Aspects of the smart city are found also in concepts such as the "digital city", but the two concepts are imperfect synonyms. Unfortunately, this gives a vague character to both concepts, because "digital city" is used in various senses in anthropology and to denote cityscapes within gameworlds. As such the concept of digital city is imprecise. Unfortunately, the literature dedicated to smart cities has converged in the past decade to denote sustainable and digital cities as imperfect synonyms for certain aspects of the smart city. From a logical standpoint, the term "digital" has a wide extension and accordingly the properties that could be included in its intension are many and broad.

We consider it necessary to develop an excursus to give the concept "smart city" a degree of coherence and substance. It is important to stress the fact that there is no worldwide recognized definition of a smart city, nor of a robotic city, for that matter. For this reason, instead of suggesting a potentially limited definition of the term, we present several directions upon which we have predicated our own definition.

For example, the definition developed by the International Telecommunications Union [15] is so wide-ranging that we can barely see its methodological value. This definition was predicated on a multi-stakeholder approach which involved more than 300 international experts: "A smart sustainable city is an innovative city that uses information and communication technologies (ICTs) and other means to improve quality of life, efficiency of urban operation and services, and competitiveness, while ensuring that it meets the needs of present and future generations with respect to economic, social, environmental as well as cultural aspects" [15].

This definition entails an ensemble of terms from multiple areas of discourse. From an epistemological standpoint, it is difficult to use such a definition to coalesce a corpus of scientific knowledge. We were left with multiple ways to represent smart cities, from various sources. Accordingly, we identified several dimensions that are almost always included in the various descriptions and definitions of the smart city. The first dimension that is always included is technology, as Mosco emphasizes [16]. However, definitions centered on technology alone, or those in which technology is correlated with various types of data, are deceptively simple. For example, one definition that is repeatedly mentioned is that developed by IBM. According to this, a smart city "makes optimal use of all the interconnected information available today to better understand and control its operations and optimize the use of limited resources" [17]. Such a definition emphasizes the role of technology in enhancing understanding, control and optimization. However, the relevance of these three aspects is questionable at best: for example, does their enhancement contribute to or reduce inequality? Do they limit our free will? Do they contribute to the increase of our security and/or quality of life? All these questions have previously been answered in a limited manner. Similarly, Cisco defines a smart city as an urban area that entails "scalable solutions that take advantage of information and communications technology (ICT) to increase efficiencies, reduce costs and enhance quality of life" [18]. This definition also entails three aspects: efficiencies, cost reduction and enhanced quality of life. Again, their significance is questionable at best [16].

Another dimension that often appears in the various attempts to define smart cities is citizen focus. For instance, British Standards Institution asserts that smart cities involve "the effective integration of physical, digital and human systems in the built environment to deliver a sustainable, prosperous and inclusive future for its citizens" [19]. Alternately, Caragliu et al. suggested a different citizen-focused definition: a city can be defined as smart "when investments in human and social capital and traditional (transport) and modern (ICT) communication infrastructure fuel sustainable economic development and a high quality of life, with a wise management of natural resources, through participatory governance" [20]. This definition was a turning point because it broadens the purpose of smart cities by encompassing people, technology, development, sustainability, quality of life and shared governance.

Certainly, it is necessary to expand the meaning of the smart city beyond its technological dimension. A technology-centered definition of the smart city may entail a somewhat paradoxical situation in which "a lot of smart city development ends up helping those who need it the least" [21]. Sustainability is in fact at least as important as technology, if not more so. It entails initiatives regarding the conservation of the environment and the development of urban settings, meant to address a plethora of challenges. Correlated with sustainability and technology are other relevant features of a smart city including effective and hyper-functional public transportation systems and progressive city planning. Last, but certainly not least, people should be able to live and work within the smart city and capitalize on its resources. One definition that includes all these dimensions was coined by The Welding Institute (TWI): "a smart city uses a framework of information and communication technologies to create, deploy and promote development practices to address urban challenges and create a joined-up technologically-enabled and sustainable infrastructure” [22]. However, in this definition “sustainability” is used in a manner that detracts from the full potential of the concept. We used the concept of the smart city with the aspects described by [23].

We agree that sustainability is predicated on infrastructure and the careful development of urban space via the Sustainable Development Goals (SDGs), but it also encompasses concerns about the environment, the autonomous character of a smart city, and its multi-layered and redundant intelligent transportation systems. The SDGs are a set of priorities that address humanity’s most pressing challenges, deriving from the United Nations 2030 Agenda presenting a plan of action based on three axes: people, the planet and prosperity [24]. The autonomous character of a smart city is an important piece of the “puzzle” surrounding its definition. Thus, its sustainability and implicit autonomy is predicated on the concept of circular economy (CE). Upon reviewing more than 100 definitions of circular economy, Kirchherr et al. developed a comprehensive definition, which we consider apt for our article: circular economy is “an economic system that is based on business models which replace the ‘end-of-life’ concept with reducing, alternatively reusing, recycling and recovering materials in production/distribution and consumption processes, thus operating at micro level (products, companies, consumers), meso level (eco-industrial parks) and macro level (city, region, nation and beyond), with the aim to accomplish sustainable development, which implies creating environmental quality, economic prosperity and social equity, to the benefit of current and future generations” [25]. This allows us to better sketch a working definition for the smart city, without losing the formidable methodological potential of sustainability.

Regardless of the aspects that are brought into the foreground, a smart city is a space loaded with juxtaposed significances, which means that it is a semiotic place. Therefore, while we admit that the term “smart” is ambiguous, we expand Giffinger et al.’s dimensions [26] upon which a definition of smart city can be developed. We assert that any definition of a smart city must take into consideration at least the following dimensions: (a) circular economy; (b) intelligent transportation systems; (c) interactive administration based on Internet of Things feedback systems; (d) people, who should be qualified human capital [27]; (e) quality of life or lifestyle; (f) sustainability of the environment and urban landscape. Therefore, we define a smart city as an interactively administered urban place that entails juxtapositions between a circular economy and intelligent transportation systems, based on information and communication technologies (ICTs), in order to increase the quality of life of its inhabitants and attain sustainability.

In the second decade of the 21st century, sustainability is a notion that crosses all aspects of life and demands our focus as a result of the haphazard use of natural resources and the harm done to the environment. More specifically, the idea of sustainable development in relation to a smart city represents a multidimensional concept that includes economic, social, and political aspects highly related to quality of life [28]. It entails satisfying the existing needs of the inhabitants of a smart city without putting at risk the needs of future generations, with a limit that consists in appropriate respect for the environment and with the aim to improve life quality through technological development [29]. Sustainability in a smart city is most often described as involving the reduction of consumption, recycling various resources, altered patterns of production and consumption, use of various types of renewable energy, and intelligent transportation systems [30].

2.2. Scientific Character of a Theory

In decision theory, the function of multi-attribute utility is generally employed to illustrate the proclivities of an agent during a potential choice. The fundamental hypothesis of this theory is that a decision-maker chooses the alternative that entails the greatest multi-attribute utility from those available. The decision has multiple value dimensions, which are generally in opposition. In a narrow sense, the techniques derived from multi-attribute utility theory are useful for enabling complex decisions. In a broad sense, the multi-attribute utility theory supports decision-making when an agent or "decision-maker has to choose from a limited number of available alternatives" [31].

Mean field theory is used in order to research the behavior of high-dimensional random models by using a simpler model as a point of reference. Thus, the characteristics of complex stochastic dynamical systems can be studied through mean-field statistical assumptions. This theory doesn't offer the possibility of interpreting complex systems: it is an "approach to understanding stochastic systems with sparse dependency structures" [32]. The theory originates in physics, and has been used in biology, social sciences, and even scientific fields such as cybernetics.

The theory of ubiquitous computing is used to describe, explain and predict computing environments in which users have the opportunity to "communicate information using any device on any network (portable) and information is transmitted in the optimal method as the context of users' requirements are autonomously recognized while the users are not aware of it" [33]. This theory is predicated on the assertion that computing technology becomes almost invisible when embedded in a plethora of objects in order to increase the quality of services [34].

Sensemaking theory in information and computer technology primarily addresses microlevel processes. It is grounded in the developments from philosophy, sociology and social psychology, in order to: (a) develop a theory and an associated methodology that allows scientists to identify, study and bridge gaps of time, space, movement and/or interaction between an existing situation and a planned result, through which sensemaking is implemented as a solution-generation mechanism [35]; (b) describe a process that entails learning loops in order to develop complex information for various tasks, such as problem-solving and decision-making [36]. The theory of sensemaking offers decision-makers a structured process for dealing with uncertainty [37].

Fuzzy set theory is used in order to study problems about ambiguous and imprecise judgements. It is an addition to classical set theory and addresses the classes of objects that have vague boundaries. Accordingly, those objects have various levels of membership. Fuzzy set theory allows the use of vague concepts in multiple domains in which the available data is ambiguous or incomplete.

Traffic flow theory concerns the interactions of pedestrians, vehicles and infrastructure. The purpose of this theory is to comprehend and improve a transport network with well-organized movement of traffic and negligible traffic problems. Briefly, this theory aims to "describe in a precise mathematical way the interactions between the vehicles and their operators (the mobile components) and the infrastructure (the immobile component)" [38]. Traffic flow theory is essential in models used for designing highways, freeways, roads, streets, etc.

Dynamic network slicing theory concerns the ways in which specific capabilities are arranged in network slices. It refers to the study of the various forms of virtual network architecture. It uses principles that have been employed for developing software-defined networking and network function virtualization in fixed networks. Dynamic network slicing theory allows decision-makers to design, deploy and customize multiple network slices atop a common network infrastructure [39].

Matching theory addresses the development of reciprocally beneficial associations over time. It is the basis for a framework that has emerged as valuable for wireless resource allocation, which can surmount some limitations of game theory and centralized optimization approaches. Matching theory offers mathematically controllable solutions for the combinatorial problem of matching players from two distinct sets, in accordance with each of the players' information and preferences [40].

Computational theory has been developed over the past century into a branch of theoretical computer science. Its aim is to develop "formal mathematical models of computation that reflect real-world computers" [41]. It entails using algorithms to categorize and solve problems. Computational theory can be divided in computability theory, complexity theory and automata theory.

Grounded theory was developed by Glaser and Strauss in the field of sociology. As a methodology it entails the development of theories. Grounded theory was initially used by sociologists and psychologists in qualitative studies, which were predicated on a research question. The data collected during research is analyzed and interpreted and may lead to the emergence of conjectures and concepts. Then, researchers code the concepts, in order to group them into themes and nodes. These nodes are clustered into categories, which in turn become the basis of a hypothesis. Finally, the hypothesis is the nucleus of a new theory that is coalesced into an ensemble of sentences. From an epistemological standpoint, grounded theory is radically different from other models of research [42].

3. Materials and Methods

3.1. Research Design

The procedure employed to select papers from the literature followed specific principles of the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) protocol [43]. The flow diagram in Figure 1 shows the research process, which follows certain well-defined steps: (1) literature search in different databases; (2) identification of papers related to the chosen topic; (3) content analysis and selection of final papers; (4) data extraction. The detailed workflow of the selection of papers is presented in Figure 1.

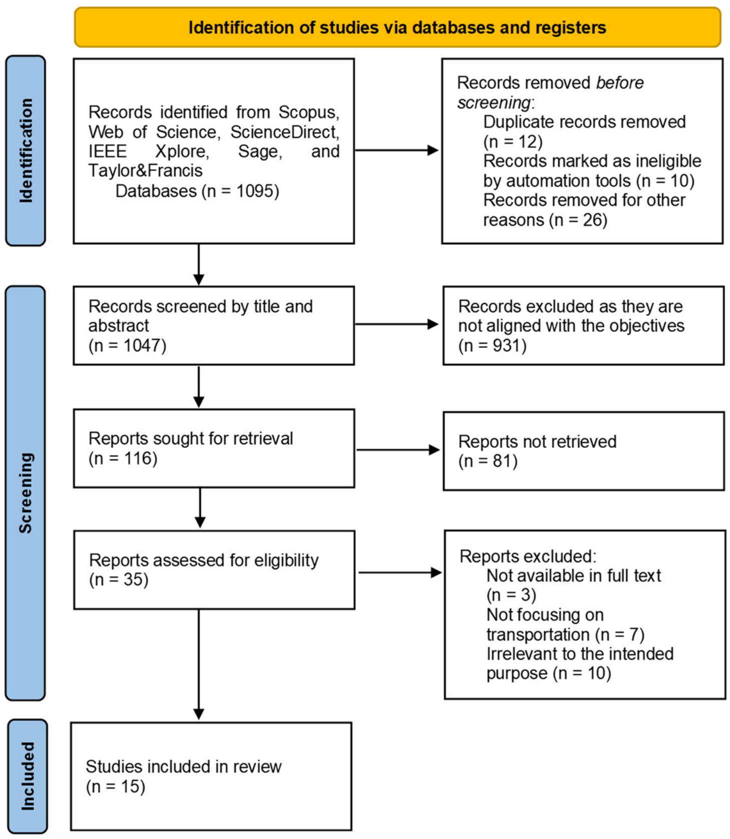

Figure 1. Research methodology following PRISMA guidelines.

3.2. Protocol and Registration

No protocol was used for the article selection and analysis process, but the recommendations provided in [44] were followed, and were discussed by the three authors at the beginning of the search process.

3.3. Eligibility Criteria

The review included published English-language scientific articles. Only full-text available articles published in peer-review journals were considered. Review papers were also included in the analysis. In terms of time, we did not impose any restrictions on the date of publication.

Scientific studies that did not deal with the concepts of smart city and transportation or were published in a language other than English were excluded. Conference papers, book sections, short papers, technical reports, editorial letters, theses, non-academic publications, and duplicated studies were also excluded.

3.4. Information Sources

The search was conducted using six scientific databases: Scopus, Web of Science, ScienceDirect, IEEE Xplore, Sage, and Taylor&Francis. The first search was performed on 11 February 2022 and was repeated on 6 May to identify new works published after the initial search.

3.5. Search Terms

The search strategy included keywords like "smart city", "robotic", "transportation" and synonyms of these concepts, combined via the "AND" Boolean operator. The search string combination was the following: ("smart city" OR "intelligent city" OR "digital city") AND (robotic *) AND ("transport" OR "transportation" OR "traffic").

3.6. Study Selection

Using EndNote 20.2.1.15749 (Clarivate, Philadelphia, PA, USA) [45], the search results from the six databases were processed. First, the duplicate sources were removed and then the three reviewers independently performed title, abstract, and full-text screening, considering the inclusion and exclusion criteria. Disagreements and discrepancies were resolved through discussion and consensus between the authors. The data from the selected papers were then extracted into Excel sheets.

4. Results and Discussion

A total of 1095 papers were retrieved, and after removing duplicates, conference papers, book sections and other sources described in the exclusion criteria, 1047 papers remained. After the initial screening process of titles and abstract, 116 papers remained. In the full-text screening phase, 81 articles were excluded. Finally, a set of 15 papers were selected which met all the conditions of the inclusion criteria.

The number of citations of the 15 papers at the time of the literature search is presented in Table 1. This information presented in the table provides a measure of the impact of the selected works.

Table 1. Number of citations of selected papers.

Item	Reference	Paper Type	No. of Citations in Scopus	No. of Citations in WoS	No. of Citations in Science Direct
1	[46]	Research article	57	67	69
2	[47]	Research article	11	13	13
3	[48]	Review article	17	20	24
4	[49]	Review article	0	1	-
5	[50]	Research article	17	27	27
6	[34]	Research article	40	42	42
7	[51]	Review article	4	8	10
8	[52]	Research article	2	4	4
9	[53]	Review article	5	9	10
10	[54]	Research article	3	4	4
11	[55]	Review article	1	2	2
12	[56]	Review article	-	0	0
13	[57]	Research article	88	115	117
14	[58]	Review article	0	0	-
15	[59]	Review article	-	0	0

The selected papers were published in 10 journals, among which four works were published in *Sustainable Cities and Society*, a high-ranked journal focusing on research into sustainable and socially resilient cities. An overview of the journals in which the 15 papers were published and the measures of their importance and influence is presented in Table 2. Paper titles, year of publication and the journal name are summarized in Table 3.

Table 2. Overview of journals.

Journal Name	Impact Factor	SRI	No. of Selected Publications
Annual Reviews in Control	6091	2477	1
Computer Communications	3167	1066	2
Future Generation Computer Systems	7187	1987	2
Information Sciences	6795	2277	1
Intelligent Systems with Applications	-	-	1
Microprocessors and Microsystems	1525	0582	1
Robotics and Computer-Integrated Manufacturing	5666	1568	1
Sustainable Cities and Society	7587	2232	4
Transportation Planning and Technology	1278	0460	1
Transportation Research Record	156	0934	1

Before discussing the scientific character of the theories identified in our review, it is necessary to expound some preliminary considerations. The various studies dedicated to smart cities and their transportation systems generally entailed theoretical approaches which required analysis in order to ascertain their relevance for obtaining valid scientific data. We readily recognize the fact that this is not only a methodological problem, but an epistemological problem as well. Therefore, to ascertain the scientific character of the theories mentioned in the reviewed articles, we used Popper's thesis regarding their falsification: we expounded "a logical characterization of such falsifiable systems" [60]. Popper recognized the fact that it is easy to obtain confirmations of specific hypotheses when developing empirical research based on a certain theory. However, the assertions emerging from such confirmations offer little more than circumstantial evidence, and do not confirm the scientific character of the theories. The scientific character of a theory is given by its falsifiability and eventual falsification.

Table 3. Overview of selected papers.

No.	Ref.	Title	Year	Journal
1	[46]	Providing secure and reliable communication for next generation networks in smart cities	2020	*Sustainable Cities and Society*
2	[47]	Multi-sensor information fusion for Internet of Things assisted automated guided vehicles in smart city	2021	*Sustainable Cities and Society*
3	[48]	Emerging research topics in control for smart infrastructures	2016	*Annual Reviews in Control*
4	[49]	Telecommunications- and information technology–inspired analyses: Review of an intelligent transportation systems experience	2017	*Transportation Research Record: Journal of the Transportation Research Board*
5	[50]	A future intelligent traffic system with mixed autonomous vehicles and human-driven vehicles	2020	*Information Sciences*

Table 3. *Cont.*

No.	Ref.	Title	Year	Journal
6	[34]	A methodological framework for assessment of ubiquitous cities using ANP and DEMATEL methods	2018	*Sustainable Cities and Society*
7	[51]	Amalgamation of blockchain and IoT for smart cities underlying 6G communication: A comprehensive review	2021	*Computer Communications*
8	[52]	Development of circular economy in smart cities based on FPGA and wireless sensors	2021	*Microprocessors and Microsystems*
9	[53]	Industrial Blockchain: A state-of-the-art Survey	2021	*Robotics and Computer-Integrated Manufacturing*
10	[54]	Urban expressway parallel pattern recognition based on intelligent IOT data processing for smart city	2020	*Computer Communications*
11	[55]	Green energy harvesting strategies on edge-based urban computing in sustainable internet of things	2021	*Sustainable Cities and Society*
12	[56]	A survey on blockchain for big data: Approaches, opportunities, and future directions	2022	*Future Generation Computer Systems*
13	[57]	BlockIoTIntelligence: A Blockchain-enabled Intelligent IoT Architecture with Artificial Intelligence	2020	*Future Generation Computer Systems*
14	[58]	The value propositions of Smart City Mobility projects	2021	*Transportation Planning and Technology*
15	[59]	Using 5G in Smart Cities: A Systematic Mapping Study	2022	*Intelligent Systems with Applications*

Basically, to ascertain the validity or otherwise of the theories mentioned in the studies presented in the reviewed articles, we used the following theses: (a) "a theory is falsified only if we have accepted basic statements which contradict it" and (b) a theory is falsified "only if we discover a reproducible effect which refutes the theory" [60]. In other words, the scientific character of the theories identified in our systematic review was verified according to the following principle: we accepted the falsification of a theory "if a low-level empirical hypothesis which describes such an effect" was suggested and corroborated [60]. This type of hypothesis is referred to by Popper as a falsifying hypothesis. The empirical character of the falsifying hypothesis entails a specific logical relationship to possible basic statements. In turn, these statements can have two roles: (I) the system of all logical basic statements allows a researcher to obtain logical characterization in "the form of empirical statements" [60]; (II) the accepted basic statements are essential for the corroboration of hypotheses. In Table 4 we offer a framework for the theories identified in the reviewed articles.

When addressing the scientific character of the theories that we identified in the aforementioned articles, we wanted to see whether or not the limits of the theories used were expounded. Furthermore, we reviewed how the theories used were instantiated and whether their validity was presented. We were particularly interested in ascertaining whether or not the two articles detailing the development of grounded theories contained any references to their degree of testability; to be more exact, we wanted to know whether they contained any mention of their falsifiability or falsification. The scientific character of any theory, including grounded theories, is proven if it can be falsified: namely, if there is at least a singular basic statement about an event (i.e., a "homotypic" basic statement) that falsifies the theory.

Table 4. Theories identified in articles dedicated to smart cities, intelligent transportation systems and the Internet of things.

No.	Application Domain	Theory	Theory's Assessment
1	Smart city services and infrastructures	QoE game theory	Verification/Confirmation
2	Sustainable transportation process/Intelligent transportation systems	Graph theory model	Verification/Confirmation
3	Smart city services and infrastructures	Control theory, theory of incentives, game theory, contract theory	Verification/Confirmation
4	Intelligent transportation systems	Entropy maximization or information theory, multi-attribute utility function/decision theory	Verification/Confirmation
5	Intelligent transportation systems	Mean-field theory	Verification/Confirmation
6	Smart city services and infrastructures	Theory of ubiquitous computing	Verification/Confirmation, Description of theoretical limits (not falsification per se)
7	Smart city services and infrastructures	Game theory	Verification/Confirmation
8	Smart city services and infrastructures	Branch line coupling theory	Verification/Confirmation
9	Industrial Blockchain	Technology acceptance model (TAM), principal agent theory (PAT), technology readiness index (TRI) and theory of planned behaviour (TPB), sensemaking theory	Verification/Confirmation
10	Intelligent transportation systems	Fuzzy set theory, traffic flow theory, probability theory, texture primitive theory	Verification/Confirmation
11	Sustainable smart cities, smart city services and infrastructures	Dynamic network slicing theory	Verification/Confirmation Methods' limits (not falsification per se)
12	Blockchain, smart city services and infrastructures, intelligent transportation systems	Matching theory, game theory, number theory	Verification/Confirmation Methods' limits (not falsification per se)
13	Blockchain, Internet of Things	omputational theory	Verification/Confirmation Methods' limits (not falsification per se)
14	Smart city services and infrastructures	Grounded theory	Verification/Confirmation Methods' limits (not falsification per se)
15	Smart city services and infrastructures	Grounded theory	Verification/Confirmation Methods' limits (not falsification per se)

We used Popper's method to emphasize the fact that falsifiability can be a criterion for expounding the empirical facets of a theory as a coherent system of statements. It is important to emphasize the fact that there is a clear distinction between (i) falsifiability and (ii) falsification. The former (i) is "a criterion for the empirical character of a system of statements", while the latter (ii) entails rules "which will determine under what conditions a system is to be regarded as falsified" [60]. Accordingly, we identified 15 articles in which there are references to theories relevant for our review.

The majority of the conclusions and results emerging from the articles reviewed that claim to be scientific are actually based on the unsound logic of verification and confirmation rather than falsification. Thus, six of the articles reviewed included either theoretical or methodological limits. However, these were not limits to the theories per se, nor were they associated with singular basic statements regarding events that could falsify the theories. Obviously, this has the detrimental effect of reducing to the category of logically false universal instantiations the majority of conclusions about (a) smart city services and infrastructures, (b) intelligent transportation systems and (c) blockchain/Internet of

Things,. In other words, it removes them from the realm of legitimate scientific theories. Moreover, the application of verification and induction as a paradigmatic approach (i.e., entailing values and methods associated with the "verified" theories) explains some of the contradictory results obtained. In Figure 2 we illustrate the number of theories associated with each application domain. It is important to notice that some of the application domains overlap.

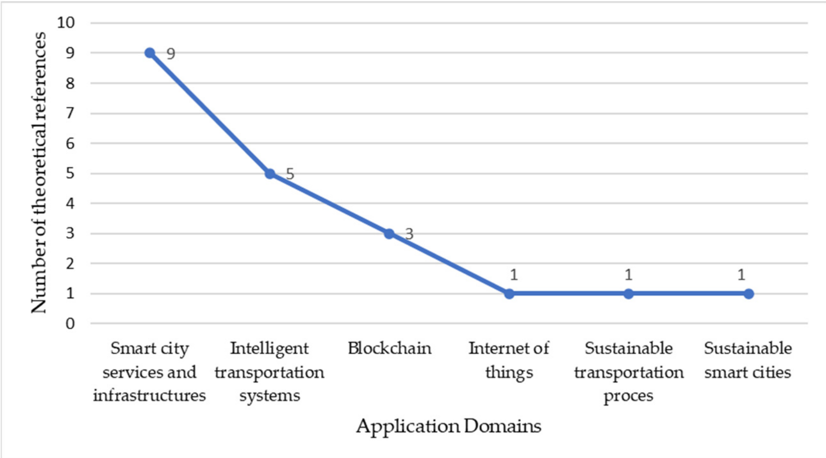

Figure 2. Theories associated with each application domain.

Essentially, our systematic review underlined an insidious type of danger that may occur in any specific application domain: a systematic indoctrination of scientists into the theories, methods, beliefs and values that dominate a particular area of empirical research. This problem appears to be more pervasive in (a) smart city services and infrastructures and (b) intelligent transportation systems. Indeed, the method by which the scientific character of the theories from these domains can be proven, namely falsification, is virtually ignored. Thus, potentially biased claims under the guise of genuine scientific theory may be used as grounds for future developments.

However, despite the fact that studies in the domains of (a) smart city services and infrastructures and (b) intelligent transportation systems are not always able to meet the standards of scientific validity, this does not necessarily imply that empirical research is entirely worthless. Many studies in both fields are engaging, and many new discoveries may emerge from these work fields including sustainable transportation processes and sustainable smart cities. We assert that policy documents that delineate research protocols should adopt more modest expectations regarding the empirical results achieved in these application domains. Furthermore, aside from moderating the expectations of empirical studies, it is important for the various actors that have agency in these domains (e.g., funding agencies, policy developers, various stakeholders) to support areas of inquiry that go beyond scientifically based practices, into areas of epistemology.

We assert that the reviewed articles dedicated both to (a) smart city services and infrastructures and (b) intelligent transportation systems contain references to theory confirmation and no references regarding their limitations. From an epistemological standpoint, potentially incorrect assertions under the semblance of scientific theories may be used as the basis for further research. Our findings are relevant because they show a systemic problem regarding the ways in which these theories are used and abused, by not considering their limitations when they are employed in studies dedicated to smart cities. Scientific research involves not only attempts to confirm theories, but also to determine the relevance of those theories for the topics approached.

Our research limitations consisted in the possibility of omitting relevant articles because of issues related to the applied search methodology, such as improper choice of search terms or exclusion of studies published in conference proceedings or book chapters, or in languages other than English. Also, aspects of the smart city vary from one author to another and from one article to another, due to the fact that they were developed by specialists in different fields.

5. Conclusions

The review presented in this article entailed an analysis of multiple studies and theories about smart cities and intelligent transportation. Our review allowed us to gain in-sights into the corpus of knowledge that has developed around concepts such as "smart city", "robotic city", and "intelligent transportation system". Notably, in the reviewed literature there is still no agreement pertaining to the definition of "smart city", "robotic city", or "intelligent transportation system". We assert that the theories used to study the realities associated with these concepts can be better employed if such definitions are coalesced into a more homogenous body of scientific literature.

We claim that Popper's method of establishing the scientific character of a theory is one of the most rigorous ways to establish a coherent body of knowledge about smart cit-ies and other related concepts. We consider falsifiability to be a satisfactory criterion for delineating the limitations of the theories used in the existing research associated with the aforementioned concepts. Furthermore, Popper's epistemological method is useful for expounding the empirical facets of the theories mentioned in this article as coherent sys-tems of statements. Clearly, there is distinction between (i) falsifiability and (ii) falsification; the former (i) is useful for establishing the empirical potential of a theory, while the latter (ii) entails rules that allow us to ascertain the conditions under which a theory is falsified [60].

Most conclusions and results expounded in the articles reviewed that claim to be scientific are arguably based on the unsound logic of verification and confirmation, rather than falsification. For example, we identified descriptive articles that had obvious theoretical and methodological limits. These limits were not integral to the theories per se, nor were they associated with basic observational statements that falsified the theories. This has the detrimental effect of reducing to the category of logically false universal instantiations the majority of conclusions about (a) smart city services and infrastructures, (b) intelligent transportation systems and (c) blockchain/Internet of Things.

In summary, without a clear method of establishing their scientific character, the reviewed theories cannot be considered legitimately scientific from an epistemological standpoint. The repeated use of verification and induction as paradigmatic approaches (i.e., entailing values and methods associated with the "verified" theories) explains some of the contradictory and disparate results obtained.

A direction for future research that may yield interesting results will be to expound and develop grounded theories that may help researchers to analyze and explain in a diachronic manner the ethical implications of the multiple processes and interactions determined by IoRT in robotic cities. The existing literature dedicated to the concepts of "smart city", "robotic city" and "intelligent transportation systems" can be used as a basis for epistemological analysis predicated on the purpose of verifying and expanding the existing theories.

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