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Review

Methodological Proposals for the Development of Services in a Smart City: A Literature Review

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Abstract: This literature review analyzes and classifies methodological contributions that answer the different challenges faced by smart cities. This study identifies city services that require the use of artificial intelligence (AI); which they refer to as AI application areas. These areas are classified and evaluated, taking into account the five proposed domains (government, environment, urban settlements, social assistance, and economy). In this review, 168 relevant studies were identified that make methodological contributions to the development of smart cities and 66 AI application areas, along with the main challenges associated with their implementation. The review methodology was content analysis of scientific literature published between 2013 and 2020. The basic terminology of this study corresponds to AI, the internet of things, and smart cities. In total, 196 references were used. Finally, the methodologies that propose optimization frameworks and analytical frameworks, the type of conceptual research, the literature published in 2018, the urban settlement macro-categories, and the group city monitoring–smart electric grid, make the greater contributions.

Keywords: artificial intelligence; internet of things; city services; smart cities

1. Introduction

A city can define itself as intelligent when investments in social and human capital, modernization of information, communication technologies (ICT), and transport infrastructure stimulate sustainable economic growth, combined with a high quality of life and sustainable management of natural resources from participative governments [1]. Currently, the international organization for standardization (ISO) provides a set of indicators that measure progress towards a smart city. They evaluate issues regarding the quality of city services, quality of life, complex risk management, and sustainable development. The smart city concept originated from five definitions including those of the intelligent city, information city, knowledge city, digital city, and (in a similar term to smart city itself) ubiquitous city u-City. These conceptual differences have some characteristics in common with different emphases and scopes [2]. The integration of resources using ICT is a principle for the creation of a smart city. Large volumes of data are generated by the internet of things (IoT), supported by artificial intelligence.

The administration of city services generates big data by obtaining, analyzing, and storing information and from making it freely available. Analysis of these large volumes of data requires the continuously implementing methodological advances in all AI application areas.

According to Mathur and Modani [3], the term AI could be defined as "the science and engineering of making intelligent machines". Therefore, a machine can be defined as "intelligent" when it carries out cognitive functions, such as learning and problem solving, associated with the human mind. For Agiwal et al. [4], the IoT is seen as the most promising technology to realize the vision of connected life as it comprises a comprehensive network of electronic devices, such as computers and electrical appliances, that are capable of communicating with each other.

Smart city concepts are in constant development and are anticipated to evolve further as their application gains popularity and they are adopted more frequently [5]. According to Chamoso et al. [6], there are currently several different technological platforms that provide support to AI application areas in smart cities—examples include sentilo, smartsantander, IBM intelligent operation center, citySDK, open cities, i-SCOPE, and open source IoT platforms to name a few.

AI techniques, such as machine learning, data science, data classification, or deep learning, enable the automation of activities related to human thinking, such as decision-making, learning, classification, and problem-solving [7].

1.1. ISO Standards for Sustainable, Smart, and Resilient Cities

The regulations for obtaining standardized metrics, which facilitate comparison and feedback between cities, is made up of a wide family of ISO 37100 standards. One of the first of these was ISO 37120 "Sustainable cities and communities—indicators for urban area services and the quality of life", which led to the creation of two new standards: ISO 37122 [8], "indicators for smart cities" and ISO 37123 [9], "indicators for resilient cities".

Cities need quality data for decision-making and the ISO 37120: 2014 standard series [10] addresses this problem through definitions, measurements, and information mechanisms agreed upon for all cities. It also offers recommendations on what to measure and how to measure it and is the base norm for cities to create globally normalized data [11]. The ISO 37122 standard allows the design of a smart city maturity model, evaluating 80 sustainability indicators, distributed in 19 areas of analysis that converge in the six universal development dimensions of a smart city (government, infrastructure, mobility, lifestyle, economy, and environment).

ISO 37123 is the first international standard to provide a set of indicators on resilience, helping governments to determine their exposure to potential hazards and their capacity to deal with them by developing comprehensive and effective responses in disaster risk reduction. The ISO 37123 standard is complementary to the ISO 37101: 2016 [12] standard, "sustainable development in communities—management system for sustainable development". This standard was designed to help communities define sustainable development goals and establish strategies to achieve them.

In 2018, the ISO 37120 standard was updated. Moreover, 28 new indicators were added, 24 old ones were eliminated, and 10 indicators were modified. ISO 37120: 2018 [10] is composed of 104 indicators, which are classified into different topics according to the industry sectors and the services provided in the city. Services include, but are not limited to; economy, education, energy, environment and climate change, finance, governance, health, housing, population, and social conditions, recreation, security, solid waste, sport and culture, telecommunications, transport, urban/local agriculture and food security, urban planning, wastewater, and water.

To facilitate the analysis of the smart city concept, we sought to establish a novel conceptual framework summarized in Figure 1. This framework divides the smart city concept into five areas (domains, AI application areas, AI applications, AI technologies, and methodologies).

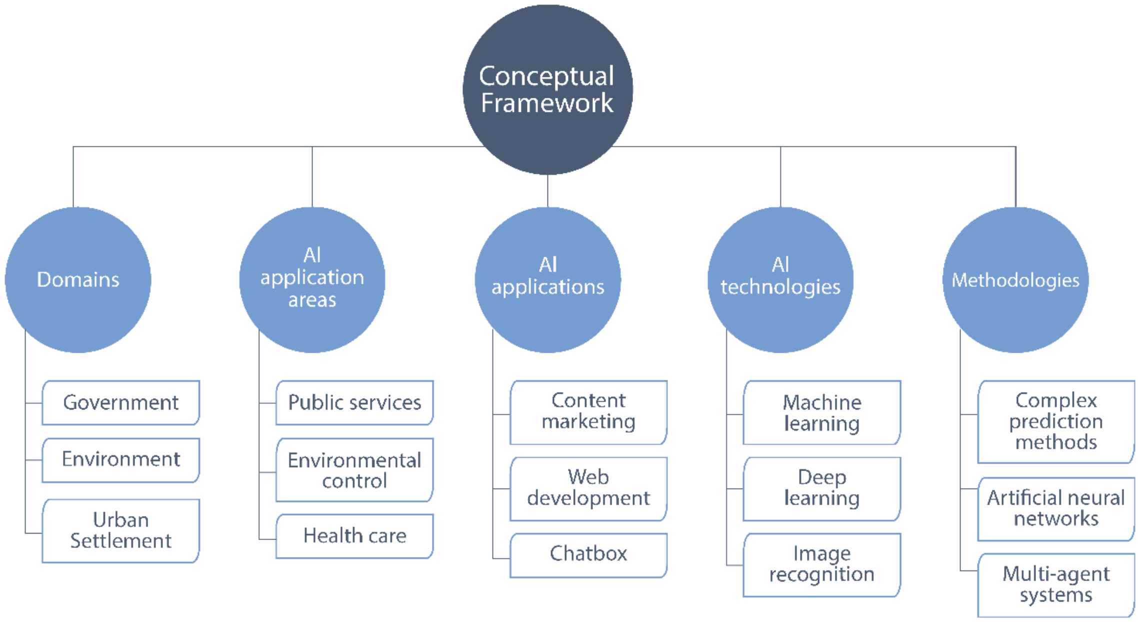

Figure 1. Schematic representation of the five study areas proposed in smart city.

The literature review of Section 4 is mainly based on numerals 1, 2, and 5 of the conceptual framework. Due to the rapid growth of urban centers, some authors, such as Dellermann et al. [13], propose grouping AI applications areas by domains, which would allow us to understand and analyze the innovations and their implementations generated within new smart cities.

The literature review of the present study is divided into five sections. Section 1 has two components; the main smart city concepts and their relationship with AI and a descriptive review of ISO 37100 members and the standards for guiding cities towards becoming a smart city. Section 2 describes the methodology used. Section 3 presents a discussion regarding different proposals by different authors for the classification of domains in smart cities and classifies the aspects of the proposed AI application areas. Section 4 reviews the literature to classify each study according to the research domain, research type, and solution methodology for each of the 66 AI application areas. Subsequently, in Section 4.6, we provide a descriptive analysis of 161 literature reviews and, finally, Section 5 presents the main conclusions of the proposed study.

1.2. Limitations and Future Work

This study is limited to literature framed in the area of engineering. All of the articles selected for the literature review were analyzed according to scientific contributions that provide solutions to the challenges presented by the smart city concept, together with the platforms that support technologies, such as IoT, AI, blockchain, cloud computing, knowledge automation, big data etc.

Based on the five definitions of the smart city concept mentioned in session 1, and taking into account the conceptual framework of Figure 1, future work could expand the discussions in the proposed study areas. For example, one of the definitions that needs to be expanded is the u-City concept, to know the impact generated by the advances of the AI application areas in social development, from a perspective framed in human and social capital [14–16].

It is essential to broaden the literature review, by focusing also on the advantages of a machine learning method for each city services group [17], e.g., in traffic management, machine learning provides the advantages to save the costs needed to create/adapt the heuristics to understand, predict, and manage anomalies in mobility [18].

2. Methodology

This work encompassed an extensive search of the literature of the most recent advances in methodological proposals for the development of the smart city concept published between 2013 and 2020, and was developed in four stages: (1) search of bibliography in indexed databases; (2) selection of investigations; (3) classification of investigations by domain; and (4) analysis of results. The methodology used was content analysis [19] to analyze different reverse logistics models [20], study progress advances in nanotechnology applied to smart packaging [21], propose a conceptual framework for strategic management [22], and classify AI methodological contributions with application to structural engineering [23].

The methodological proposal of this article, which includes identification, classification, and analysis in our case of smart city domains and services that require the methodological advance of AI, was used by Lee et al. [2] to evaluate exploitation level of services in different domains in the cities of Seoul and San Francisco.

Using the same methodology, the research by Lee et al. [24] identifies, classifies, and analyzes services, devices, and technologies for the development of smart city architecture. Likewise, Lee et al. [25] used it to propose a ubiquitous u-Eco ecological city architecture evaluating the convergence of IT services within the urban space.

This study is divided into macro-categories and groups. The macro-categories are represented by the five proposed domains and the groups represent the 66 AI application areas. In turn, each group contains the methodological proposals for each AI application area, identifying their degree of development through the number of investigations

The process of reading and literature analysis was done through the google scholar search engine using the WOS—Scopus digital platforms and mainly utilizing databases such as Springer Link, EmeraldInsight, Science Direct, Wiley Online Library, Taylor & Francis Group, and IEEE Xplore Digital Library, among others. In this study, 5600 publications in scientific journals have been reviewed, of which 161 were included in the literature review. Our main research question was: what are the main domains, city services, and important methodologies that contribute to the development of the smart city concept?

3. Classification of AI Application Areas by Domain

Authors such as [26–29] established numerous domains, city services, definitions, dimensions, models, and smart city paradigms. Alamsyah et al. [26] classified domains into four groups (government, citizens, businesses, and environment). The domain of government corresponds to the ability to respond efficiently to the needs of the citizen. The citizen domain focuses on activities that generate well-being. The business domain groups all the services and techniques, which enhance the added value of activities in the city. Finally, the environment domain highlights the need to create more sustainable cities (recycling models, environmental security, and quality of information).

Authors, such as Arroub et al. [27] build their smart city vision upon the quality of life of citizens, and smart city dimensions are grouped into six domains (environment, life, smart economy, government, mobility, and people). For the authors, the environment domain seeks to improve sustainability by integrating water, green spaces, wastewater infrastructure, and green energy resources. The life domain corresponds to the ability to use technology to improve the quality of life of citizens. The smart economy domain establishes synergic characteristics; innovation, social responsibility, competitiveness, digital cloud computing, and circular economy, generating value within the commercial, financial, service-based, and productive activities of the city. The government domain corresponds to the relationships, laws, regulations, practices, information, and rules that allow interaction between all interested parties. In the mobility domain, the transport systems are interconnected in real-time and there are multiple options, preserving quality service and optimization. For [30,31], the IoT and ICT allow the development of a new generation of urban traffic control and traffic management systems. Finally, the personal domain focuses on the importance of creativity, knowledge, learning, and education.

Oktaria and Suhardi [28] classified domains into three groups (urban settlement, social service, and economy). The urban settlement domain concentrates all the physical assets of the city (centralization and distribution of government services) and establishes the monitoring and control capacity of the city. The social service domain provides the community with social welfare (education, health, and social care) and the economy domain allows the generation of added value in the city (transport, financial services, industry and commerce, tourism, and culture).

Authors such as Raaijen and Daneva [29] classify smart city challenges into eight domains (technical infrastructure, application domains, system integration, data processing, governance and management, society and citizens, business domain, and environmental sustainability). The authors group the first four domains as technical challenges that require the capacity for innovation in the city's infrastructure. The second group is characterized by qualitative aspects such as culture, environmental protection, and government strategies capable of establishing relationships with all stakeholders.

Table 1 describes the classification structure of AI application areas in the investigations of [26–29]. Based on these investigations, we identified 66 areas where AI needs to be used and classified into five domains. Table 1 also presents 11 areas that were not studied by [26–29], which are proposed from our literature review and service needs of the residents of a smart city. Finally, the proposed classification structure in Table 1, together with the level of implementation of AI technology, allowed us to define how smart a city can be.

Table 1. AI application areas by domains.

Domain	AI Applications Areas	Alamsyah et al. [26]	Arroub et al. [27]	Oktaria and Suhardi [28]	Raaijen and Daneva [29]
Government	E-government and citizen participation	X	X	X	
	Transparent government	X			X
	Public service	X			
	Public safety	X			
	City monitoring	X			X
	Emergency response	X			
	City management				
	Facility and infrastructure provision controlling service				X
	Job creation, work, and employment				
	Environmental control		X	X	
	Disaster management			X	
	Crime and disaster prevention			X	
	Public and city administration		X	X	
Environment	Smart electric grid	X			X
	Renewable energy	X	X		
	Pollution control	X	X		X
	Building	X			
	Housing	X			
	Community	X		X	
	Public space				
	Waste management	X			
	Resources		X		X
	Environment		X		X
Urban Settlement	Real estate			X	
	Water management	X			
	Drainage				
	Water waste management	X			
	Environmental road infrastructure.				X
	Energy				X
	Communication and information.				
	Utilities				
	Green open space		X		
	Park			X	
	Space for the informal sector and small-medium enterprise				
	Financial service				

Table 1. *Cont.*

Domain	AI Applications Areas	Alamsyah et al. [26]	Arroub et al. [27]	Oktaria and Suhardi [28]	Raaijen and Daneva [29]
Urban Settlement	Regional information center				
	Smart city information service				X
	Tourist	X		X	
	Lodging			X	
	Travel guidance			X	
	Transportation			X	
	Road traffic control service			X	X
	Parking service				
	Vehicle information service			X	
	Culture			X	
Social Service	Learning and education			X	
	Healthcare	X	X	X	
	Welfare and social care		X	X	
	Social service center			X	
	Entertainment and sport			X	
	Worship				
	Burial			X	
	Public transport	X	X	X	
	Social cohesion	X			
	E-Services delivery			X	
Economy	Enterprise management	X		X	X
	Logistics	X		X	
	Supply chain and commerce	X		X	
	Transaction and market	X		X	
	Advertisement	X			
	Research and policy innovation			X	X
	Entrepreneurship	X			
	Agriculture	X		X	
	Center and payment service			X	
	Warehousing			X	
	Industry			X	

4. Literature Review

In these articles, we analyzed the research domain, research type and solution methodology. In total, there are 66 groups classified into five macro-categories (Table 1). The AI application areas in this study are derived from the different services that smart cities provide to their inhabitants [26–29]. Table 2 defines the categories research type/solution methodology, used in this study for the classification of methodological proposals.

Table 2. Summary of the categories research type/solution methodology.

Research Type	Solution Methodology
Conceptual research (CR): methodology in which research is carried out by observing and analyzing existing information on a given topic (conceptual frameworks, theoretical studies, methodological maps, among others).	Optimization framework (OF): studies that propose mathematical modeling to find better solutions or adjust parameters.
Quantitative study (QS): studies that have methodological developments with simulation results, most of the time; numerical data to collect concrete information, such as numbers.	Analytical framework (AF): studies that aim to organize and implement lines of inquiry to account for the object of study.
Literature review (LR): analysis and discussion by authors on a specific topic, generally scientific reports (empirical, theoretical, critical, analytical, or methodological).	Data management (DM): studies that propose data optimization models for decision making.
Case study (CS): detailed observation of a single study subject or group to generalize the results and knowledge obtained.	Adaptive framework (ADF): studies that evaluate the interaction and adaptation of systems with a common objective.
Qualitative research (QR): non-numerical data collection; studies based on surveys, interviews, a panel of experts, among others.	Access protocols (AP): studies that propose and evaluate different communication mechanisms and protocols, to share a common transmission medium.
	Communication framework (CF): studies that propose and evaluate different communication architectures.
	Hierarchical information architecture (HIA): studies that propose and evaluate architectures for data traffic control.

The 161 selected investigations may not mention direct indicators or factors associated with AI; however, these solutions generate improved configurations that contribute to AI application areas, which is essential for the development of the smart city concept.

4.1. Government Domain

Current dynamics demand that public organizations provide efficient services, with greater transparency and accessibility, taking advantage of the digital revolution [32]. E-government is a paradigm shift in government management—a management concept that merges the public administration with the use of technologies, such as AI, IoT, blockchain, etc., integrated by ICT to improve the provision of services, quality of available information, simplification of administrative processes, document management, city monitoring, disaster management, and creation of channels that facilitate greater transparency and citizen participation [33].

One of the primary objectives of e-government is to bring public administration closer to citizens and encourage their participation in public decisions. In e-government, the design and management of public policies is aimed at creating public value, that is, the value created by the government by improving the provision of public services [34]. E-government is justified insofar as it expands the capacity of the public administration to generate public value [35]. Table 3 shows some relevant studies for the government domain.

Table 3. Literature review—methodological proposals to develop the government domain of the smart city concept.

AI Application Areas	Research Domain. Research Type/Solution Methodology
E-Government and citizen participation	Big data and communities [36]. CS/AF.
	An analytical framework to bridge the knowledge gap by a specific e-government initiative [37]. CS/AF.
	Characterizing the impact of GPS signal strength on power consumption [38]. QS/OF.
	Implications and pitfalls of smart earth technologies [39]. LR/AF.
	Establishment of a digital ecosystem [40]. CS/ADF.
Transparent government	Intelligent governance [41]. CR/AF.
	An analytical framework to evaluate the role of AI, cognitive machines, and viable systems [42]. QR/AF.
	Build a general architecture for the IoT [43]. CS/AF.
	Urban planning [44]. CS/OF.
Public services	An optimization framework for urban trips in a smart city [45]. QS/OF.
	Dynamic resource partitioning for heterogeneous multi-core-based cloud computing [46]. QS/AP.
Public safety	An analytical framework to examine cybernetic security [47]. LR/AF.
	Informatics security [48]. QR/AF.
	Cybernetic attack [49]. CR/HIA.
	Crowd surveillance in a smart city [50]. QS/OF.
	Cyber threats [51]. CR/AF.
	Smart solutions for combat threats to safety and security [52]. LR/AF.
	Facial expression analysis for smart security in law-enforcement services [53]. QS/OF.
City monitoring	Big data analysis [54]. CS/DM.
	Optimization framework to image classification using 5G technology [55]. QS/OF.
	Computer vision in the IoT to automate actions [56]. QS/OF.
	Efficient management of water resources [57]. CS/OF.
	IoT-AI in smart city model [58]. CR/AF.
	Fault diagnosis in WSNs (reliability in the data) [59]. QS/OF.
	Overview of different networking architectures and protocols for smart city systems [60]. CR/CF.
	Distributed image-retrieval method designed for a cloud-computing based multi-camera system [61]. CR/OF.
	Challenges and opportunities to improve security and privacy in a smart city [62]. LR/AF.
Emergency responses	Smart digital city model using real-time urban data [63]. QS/DM.
	Model-based runtime monitoring of smart city systems to verify smart systems [64]. CR/OF.
	Emergency treatment for cardiac arrest [65]. QS/AF.

Table 3. *Cont.*

AI Application Areas	Research Domain. Research Type/Solution Methodology
City management	Fault recovery mechanism when the quality of the data streams from a smart city environment drops [66]. QS/ADF.
	An optimization framework for the prediction of the demand of patients at health centers [67]. QS/OF.
	IoT data management for smart city development and urban planning [68]. QS/DM.
	An analytical framework to evaluate the top ten challenges in the development of the smart world [69]. CR/AF.
	Importance of data management and its challenges in modern life and economy [70]. CR/DM.
	Data transmission model for urban sensing [71]. CR/DM.
Facility and infrastructure provision control services	An analytical framework to study the practical lessons from the deployment and management of the IoT infrastructure [72]. CS/AF.
	Network architecture for a smart city system design [73]. QR/AF.
Job creation, work, and employment	Role of smart ICT in advancing infrastructure and crowdsourcing future development [74]. CS/DM.
	Identification of intelligent, abstracted, and adaptive ways of correlating and combining the various levels of information [75]. CR/ADF.
	Environmental parameters in a smart city [76]. QS/OF.
Disaster management	Smart energy solutions [77]. CR/AF.
Crime and disaster prevention	Project for the analysis of air quality post-earthquake [78]. CS/AF.
	Communication framework to help solve traffic overload in resource sharing [79]. CR/CF.
	Multivariate spatiotemporal data streams to improve data prediction [80]. CR/OF.
Public and city administration	Optimization framework to smart management of public lighting [81]. CS/OF.

4.2. Environment Domain

In the long-term, the sustainability of the city is essential for its habitability and survival. An intelligent electric grid is required to connect all users and facilitate both the client consuming energy and/or delivering it to the system. Millions of electric cars connected to the grid would allow invulnerability to energy loss. The IoT would capture consumption and generation capacity in real-time and this information would be processed by AI to establish variable purchase and sale prices for each actor in the system. Likewise, an adjusted forecast of energy demand together with the information collected by sensors would allow efficient management of the electricity network in new smart cities. Roofs of houses with solar panels, micro wind turbines, hydroelectric power stations, and the tens of gigawatts of power stored in car batteries would facilitate intelligent management of the electric grid. All these technologies reduce environmental impact.

Controlling fixed and mobile pollution is another challenge for smart cities. The ability to monitor and manage polluting sources using big data would allow the intelligent reduction of energy expenditure and reduce pollution in each neighborhood of a city.

The construction of smart buildings interconnected with their physical and logical environment enables efficient management of resources, increases security and privacy, and generates more productive environments. The circular economy of interconnected areas allows positive business results to be intensified.

Finally, communities always want better public spaces and these spaces must add value to the city. Smart benches with environmental parameter sensors, entertainment with the ability to interact with citizens, or virtual reality entertainment are some examples of how AI could be used to improve interaction in public spaces. Table 4 shows some relevant studies for the environment domain.

Table 4. Literature review—methodological proposals for the development of the environmental domain of the smart city concept.

AI Application Areas	Research Domain. Research Type/Solution Methodology
Smart electric grid	Development of smart grid co-simulation platforms [82]. QS/OF.
	Integrated system with a three-tier 5G network and wireless multimedia sensor networks [83]. QS/OF.
	The vulnerability of named data networking against content poisoning attacks [84]. QS/DM.
	Smart grid approaches and IoT applications in various fields [85]. LR/AF.
	5G wideband [86]. CR/OF.
	Decision-making tool in a street lighting system [87]. CS/OF.
	Efficient routing metric for energy-constrained devices [88]. QS/OF.
	Location, automatic fault restoration, and isolation service dispatch problem [89]. QS/OF.
	Photovoltaic energy distribution [90]. QS/OF.
Renewable energy	Optimization of renewable energy sources [91]. QS/OF.
	Planning and energy operation management models [92]. LR/OF.
	An optimization framework for adjusting power requirements in WSN [93]. QS/OF.
Pollution control	Air-quality monitoring [94]. QS/CF.
Building	Data analysis [95]. QS/HIA.
	An analytical framework to understand the process of building an effective smart city [2]. LR/AF.
Housing	An analytical framework to evaluate energy consumption, public policies, and household perception of energy savings [96]. LR/AF.
	An analytical framework to implement smart home construction requirements [97]. QR/AF.
Community	Design of a communication framework for a smart city inspired by the nervous system [98]. LR/CF.
	The trustworthiness of the crowd sensed data (smartphone users) [99]. QS/OF.
	Design of an analytical framework for city development, sustainability, and ICT [100]. LR/AF.
	Examining the working arrangements and commuting habits of a sample group of employees from a company [101]. CS/AF.
Waste management	Electronic waste collection [102]. QS/OF.
	Computing models enabled IoT to develop environmental sustainability [103]. LR/AF.

4.3. Urban Settlement Domain

This domain requires an integrative strategy for the urban systems of the city. Infrastructure for basic services such as drainage and waste management is vital for a city to function.

Energy, drainage, water, waste, communication, and information services all provide well-being. This requires delivering transparent and timely information to the end-user so they can understand the effect of their consumption.

The current state of constructions (parks, open green space, space for informal sectors, and small and medium-sized companies) belongs to the visible infrastructure. The interaction of citizens with these services is visual; therefore, the user can differentiate the level of quality delivered by the service. AI can unite information regarding the use of services to support citizens—for example, pedestrian monitoring could provide services in places of greatest demand or need by inhabitants.

Transportation, traffic control, parking, and vehicle information services could be interconnected via category four vehicles. These vehicles can provide transportation services without a driver—a user requests the service, the public or private vehicle delivers the service and subsequently connects with AI to establish routes, share spaces, establish parking spaces, and/or find intelligent recharging points.

Finally, the city must achieve cultural integration. A smart city must prepare the population through education and must facilitate the integration of citizens and social inclusion. The school is still the main institution to create a sustainable environment in the long term. This socially protected environment can be analyzed using the multiple data streams obtained from the IoT throughout the city. In summary, AI would analyze the mood of the inhabitants, generate capacity for social inclusion, and make decisions regarding the different levels of services to improve integration. Table 5 shows some relevant studies for the urban settlement domain.

Table 5. Literature review—methodological proposals for the development of the urban settlement domain of the smart city concept.

AI Application Areas	Research Domain. Research Type/Solution Methodology
Real estate	Business intelligence project [104]. CS/AF.
	Statistical analysis for the evaluation of a smart real estate market [105]. CS/AF.A conceptual framework for the analysis of commercial real estate in smart cities [106]. CR/AF.
Water management	Water quality monitoring [107]. CR/ADF.
	Water demand management [108]. QS/OF.
Drainage	Real-time urban drainage monitoring [109]. CS/ADF.
	Smart urban drainage systems with real-time control [110]. QS/AF.
Water waste management	Smart water management towards smart cities [111]. CS/AF.
Environmental road infrastructure	Control system based on the integration of software-defined networks and IoT in smart city environments [112]. QS/OF.
	An analytical framework to evaluate AI methods in structural engineering [23]. LR/AF.
Energy	Intelligent control to optimize energy consumption [113]. QS/OF.
	Adaptive traffic in hierarchical WSNs [114]. QS/HIA.
Communication and information	Issues with network architecture in smart cities (high latency, bandwidth bottlenecks, security and privacy, and scalability) [115]. CR/OF.
	Appropriate mechanisms for considering the users' priorities in 5G ultra-dense networks [116]. QS/OF.
	IoT/intelligent network fusion [117]. QS/OF.
	Discussion about state-of-the-art communication technologies and smart applications [118]. LR/AF.
	Optimization framework to the diffusion of data packages in wireless multimedia sensor networks [119]. QS/OF.
	Detection model using wireless nanosensor networks (WNSNs) [120]. QS/OF.
Utilities	Smart city business models [121]. LR/AF.

Table 5. *Cont.*

AI Application Areas	Research Domain. Research Type/Solution Methodology
Green open spaces	Integration of green space and urban forest management within smart cities [122]. CR/AF.
	An analytical framework for compact and green cities [123]. CR/AF.
	Monitoring urban green spaces [124]. CR/AF.
Parks	Application for monitoring tourism in national parks [125]. CR/ADF.
Space for the informal sector and small medium enterprise	Fundamental concerns related to the technology-driven entrepreneurial vision of smart cities [126]. CR/AF.
	Impact of AI on society and firms [127]. CR/AF.
	The framework of big data-driven smart manufacturing, and their characteristics [128]. LR/AF.
Financial services	Smart financial format [129]. CR/OF.
Regional information centers	Methods and tools for a cognition-driven and personalized information system [130]. CR/OF.
	An analytical framework for the analysis of the information trade in the IoT [131]. CR/AF.
	3-D analysis platform to visualize the city's information [132]. QS/ADF.
Smart city information services	Smart services for city improvements [133]. CR/AF.
	Analysis of the life-cycle of human dynamics (human behaviors and activities) [134]. CR/ADF.
	Large scale data analytics framework for smart cities [135]. CR/AF.An adaptive framework to evaluate a smart system of emergencies [136]. CR/ ADF.
Tourism	Smart tourism technologies [137]. CR/AF.
	Smart and connected communities [138]. CS/AF.
Lodging	Smart hospitality ecosystem [139]. LR/DM.
Travel guidance	An optimization framework for classifying road obstacles [140]. QS/OF.
	An optimization framework for estimates of intelligent traffic time in smart cities [141]. QS/OF.
Transportation	Vehicular communication protocol [142]. CR/CF.
	Mobile power infrastructure planning (electric vehicle) [143]. QS/OF.
	Big data analysis for urban traffic control [144]. QS/DM.
	An optimization framework to execute intelligent transportation systems of systems operations [145]. QS/OF.
Road traffic service control	Data management for an intelligent transportation system [146]. CR/DM.
	A pedestrian monitoring system in smart cities [147]. QS/OF.
Parking services	Visual parking space monitoring [148]. CR/ADF.
	IoT smart parking system for smart cities [149]. LR/AF.
	Instant communication to find a suitable parking place [150]. CR/AP.
Vehicle information services	Structure of a broadband network for processing sensory data [151]. CR/OF.
	A common framework for urban mobility development [152]. CR/AF.
	An optimization framework for the mobile collection of e-waste on demand [153]. QS/OF.
Culture	Smart city and intercultural education [154]. CR/AF.
	Automation of audio post-production [155]. CR/AF.

4.4. Social Service Domain

Digital transformation requires public administration to plan the processes of providing social services. Currently, there is an ecosystem of technologies that directly impact the social services sector, which includes artificial intelligence, blockchain, the internet of things and the cloud, big data, and virtual and augmented reality. The characteristics of each of these technologies create a specific set of opportunities and challenges, therefore public administrators must understand which technologies will be important in each case and prepare accordingly.

The integration of sensors and nanosensors will expand the capabilities of wireless communication [156]. Smart cities require integration of all the sensors/nano sensors and cameras of the city and this information can be used by AI to detect people's facial expressions and establish the health patterns of citizens. AI will allow classifying diseases by recognizing by the tone of voice and diseases, such as Parkinson's disease, could be monitored using IoT sensors deployed around the city.

The education of the inhabitants of smart cities is essential for economic growth. AI-based instruction would enable learning objectives appropriate for everyone. Individual teaching is strengthened by peer integration and could be accomplished through AI ranking and administration.

Trade requires logistics and delivery-based e-services could sustainably facilitate the transport of goods. Drones, ground robots, public transport, and traffic control could allow the mobility of merchandise to be developed in a safe, sustainable, and low-cost manner.

Finally, welfare and social care will be the main activities of the society. The ability to establish the needs of citizens will be one of the main AI activities. Over the next decade, most of the workforce will be replaced by automation and citizens will replace paid activities with social welfare activities. Table 6 shows some relevant studies for the social service domain.

Table 6. Literature review—methodological proposals to develop the social services domain of the smart city concept.

AI Application Areas	**Research Domain. Research Type/Solution Methodology**
Learning and education	Development of the smart home concept for digital natives [157]. CR/AF.
	An analytical framework to evaluate advances in ANN and machine learning [158]. LR/AF.
Healthcare	Personalized ubiquitous cloud and edge-enabled networked healthcare system for smart cities [159]. CS/ADF.
	A facial expression recognition system to improve healthcare [160]. QS/OF.
	An optimization framework for heart failure risk prediction [161]. CR/OP.
	An analytical framework to overview big data and smart systems in healthcare [162]. LR/AF.
	An optimization framework for computer-assisted blood analysis to detect and count leukocytes [163]. QS/OF.
Welfare and social care	An adaptive framework for the development of mobile applications used for the prevention of potential epidemics [164]. CR/ADF.
Social service center	An analytical framework that determines the factors affecting e-service adoption [165]. CS/AF.
Entertainment and sport	Composition framework of semantic web services [166]. CR/OF.
Worship	Use of ICT as a way of enhancing traditional worship practices [167]. QS/DM.
Burial	Ecological multiple-use corridors [168]. CR/AF.
Public transport	Access protocols for communication between vehicles by introducing moving relays [169]. QS/AP.
	Smart controlling of traffic lights [170]. QS/OF.

Table 6. *Cont.*

AI Application Areas	Research Domain. Research Type/Solution Methodology
Social cohesion	Evaluation of the transformation processes into smart cities [171]. LR/AF.
	Deep analysis of the concept of smart social systems [172]. CR/AF.
E-service delivery	Digital public services [173]. LR/AF.
	Electronic data management system for the adoption of e-services [174]. CS/DM.
	Optimization framework to a crowdsourcing solution (last mile) in an e-commerce environment [175]. CR/OF.

4.5. Economy Domain

Business, commerce, and industry promote the growth of a city. Transparency, quality, and timeliness of the information and robust communication systems are required for a city to develop the capacity for economic growth.

AI-based cybersecurity provides the necessary protection for information. The main objective is to maintain real-time control of all ICT in the city. Industry, financial centers, markets, transactions, logistics, and entrepreneurship are all value-generating activities, which are empowered by efficient control of communication and data.

Innovation is based on human interaction and knowledge. The information required to improve innovation must be available to all actors. Additionally, the information must be presented via an intelligent interface to generate synergy in the innovation community.

Finally, other economic activities, such as agriculture and services, could be promoted with AI use. In agriculture, the recognition of pests by drones or vision cameras could reduce the use of pesticides. Additionally, machines for harvesting plants or fruits by robots are some of the latest real-world AI applications. Table 7 shows some relevant studies for the economics domain.

Table 7. Literature review—methodological proposals for the development of the economy domain of the smart city concept.

AI Application Areas	Research Domain. Research Type/Solution Methodology
Enterprise management	Optimization framework of remote monitoring services for anomaly detection [176]. CR/OF.
Logistics	An adaptive framework for IoT-enabled smart appliances under industry 4.0 [177]. CS/ADF.
	Human decision models for 4.0 industry [178]. CR/AF.
Supply chain and commerce	Business model configurations in the IoT platforms for smart city development [179]. CR/AF.
	Impact of smart new technologies on retail [180]. CR/AF.
Transaction and market	Strategic approaches of large ICT industries (IBM, Cisco, Accenture) such as technology providers [181]. CS/AF.
Advertisement	Design and implement a smart advertisement display board prototype [182]. QS/OF.
	Development AI technology in smart advertising processes [183]. CS/OF.
Research and policy innovation	A historical account of maker spaces [184]. CR/AF.
	Economic heterogeneity of different building types [185]. CR/OF.
	An analytical framework to analyze big urban data [186]. LR/AF.

Table 7. *Cont.*

AI Application Areas	Research Domain. Research Type/Solution Methodology
Entrepreneurship	Model for data management [187]. CR/AF.
	An analytical framework for understanding the contextual development of smart city initiatives [188]. CS/AF.
	Access protocol for a smart agricultural system [189]. CR/AP.
Center and payment service	Adoption blockchain to replace third-party auditors for smart payments [190]. QS/OF.
	An optimization framework for the monetization of the IoT data using smart contracts [191]. CR/OF.
Warehousing	An optimization framework for warehouse automation in smart cities [192]. QS/OF.
Industry	Decentralized data analysis integration [193]. QS/OF.
	An analytical framework to evaluate challenges and recommendations in developing smart cities and cleaner production initiatives [194]. LR/AF.
	Smart manufacturing apps with a vendor-agnostic platform [195]. CS/OF.

4.6. Descriptive Analysis of Studies

1. Distribution of publications by research type: the most evoked research type was conceptual research (with 56 research) followed by quantitative studies (with 52), case study (with 26), literature reviews (with 24), and qualitative research (with 3) (Figure 2).

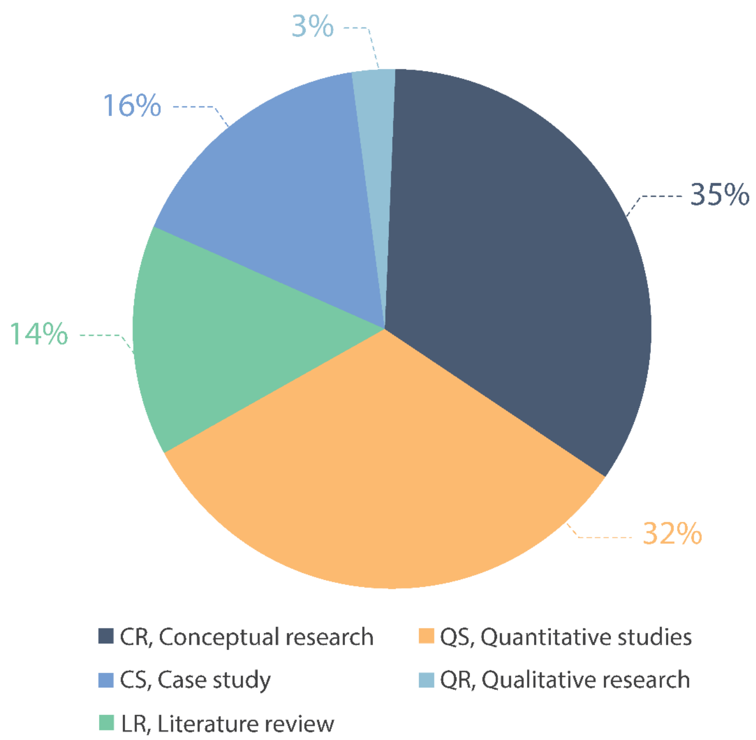

Figure 2. Distribution of studies by type of research.

2. Distribution of the solution methodologies: analysis of 161 investigations that make up the literature review shows that optimization frameworks and analytical frameworks are the most used methodological developments (with 63 research). Second, are data management (with 14).

Third, we find the adaptive frameworks (with 11). Fourth, communication frameworks (with 4). Finally, the hierarchical information architecture and access protocols (with 3) (Figure 3).

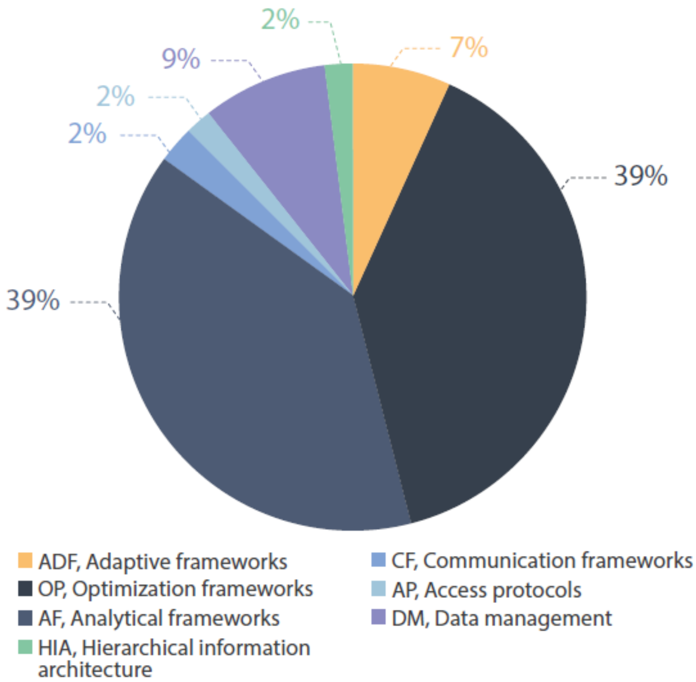

Figure 3. Distribution of the solution methodologies.

3. Several publications by year: according to [196], the number of articles using AI in smart cities increased between 2010 and 2019. This confirms the growing interest that researchers have been giving to this subject in the last years. In this study, 68 articles belonging to the literature review were published in the year 2018 (Figure 4).

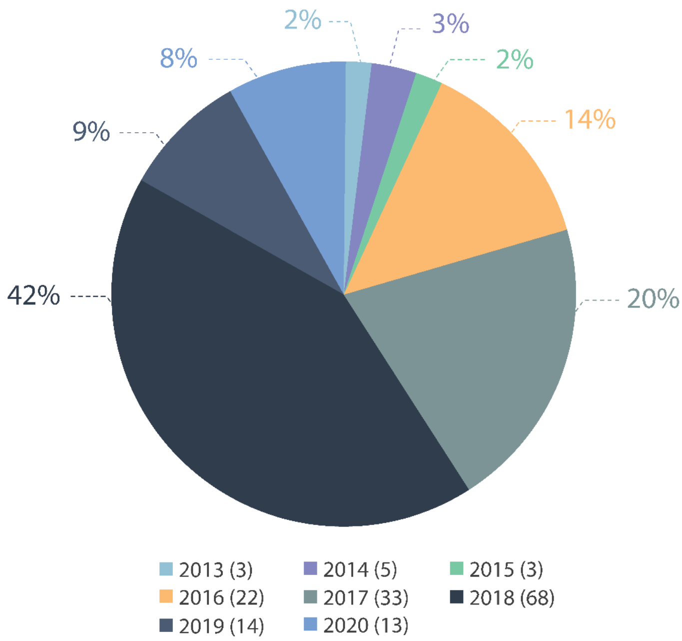

Figure 4. Number of publications years (2013–2020).

4. Several publications by domain: in the literature review, a total of five domains with 161 articles were used. The urban settlement domain was the greatest contribution (with 53 research), followed by the government domain (with 46), environment domain (with 23), economy domain (with 20), and the social service domain (with 19) (Figure 5).

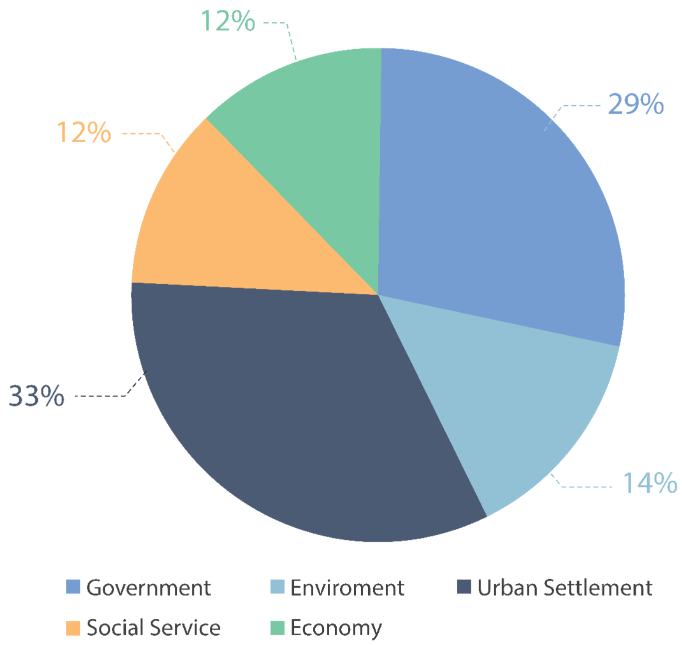

Figure 5. Number of publications by domain.

5. AI application areas in smart cities: according to our literature review, seven areas of AI application make the greatest methodological contributions. As depicted in Figure 6, the two most important are: city monitoring—smart electric grid (with 9 research), followed by public safety (with 7), communication and information—city management (with 6) and e-government and citizen participation—healthcare (with 5).

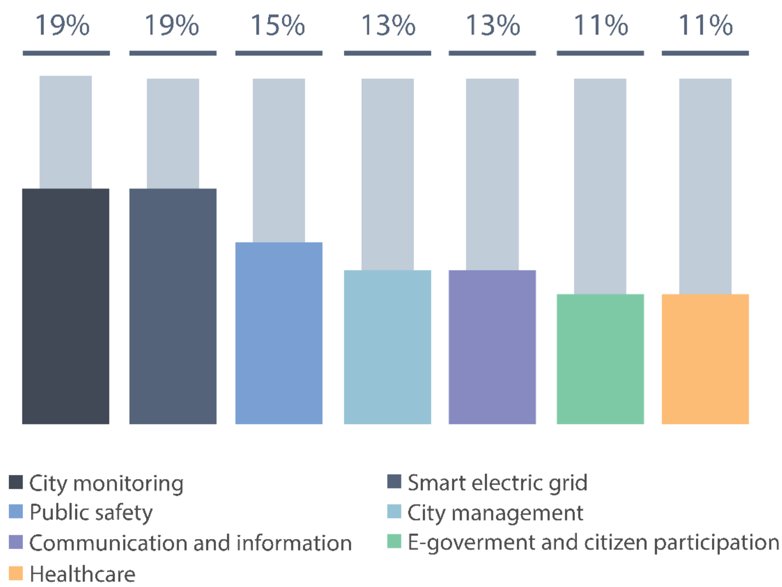

Figure 6. Distribution of the seven principal AI application areas.

5. Conclusions

This literature review discusses different challenges and solutions that AI presents for the development of smart cities. However, the solutions have different smart city concepts that do not necessarily include AI (business intelligence projects, IoT, blockchain, cloud computing, knowledge automation, platforms of technological support, big data analysis, among others) that ultimately make up improved solutions with direct application to smart cities. The extensive literature review was carried out between the years (2013–2020).

In total, 196 references were used. The majority of these involved methodologies proposed optimization frameworks, conceptual research, and urban settlement domains. Moreover, 161 studies made relevant methodological contributions. Keywords, such as artificial intelligence, internet of things, and smart cities were used.

A set of five domains with 66 AI application areas was proposed in this review. These areas allow the adequate development of sustainable and habitable smart cities. The smart city trend is to integrate available AI capabilities into all city settings; from the administration and government through to the water and energy distribution of the entire city, using the IoT and ICTs; facilitating the implementation of AI in all city domains.

The main communications problem is cybersecurity (privacy and external security-attacks), causing great damage to the operation of the city's domains. Emergency services, security, electricity, gas and water services, public transportation, and recycling are also all potentially vulnerable to third party interests to achieve economic benefits.

Through AI, the safety of people and the automation of crime control processes will allow citizen control capabilities and reduce crime. AI can recognize people with real-time images, analysis of people's behavior in public spaces, control goods in congested spaces (supermarkets, streets, or parks), and data processing city sensors. This generates positive effects on smart city citizens; developing safe environments that actively deter crime.

The use of AI improves the coverage and quality of social services. Health and education present trends and applications of great impact, ICT multiplies teaching capacity in schools and universities, and AI facilitates the diagnosis and control of diseases and virtual teaching. The administration and decision-making regarding hospital capacities are the main AI benefits in social services, improving the quality of life of smart city citizens.

There are many technical challenges associated with the development of smart cities that interconnect all AI application areas. The architecture of the systems must be open and scalable, improving the integration and optimization of new systems. These must have the ability to handle different data formats to correctly develop big data and transparency of information is essential to achieve sustained growth over time. The continuous supply of water and energy is also essential to sustain life in a smart city.

Collaboration between all city actors requires a technological base capable of integrating the domains with AI application areas. This integration improves the ability to achieve a sustainable and citizen-friendly city. AI must be adopted by society and it must be open, decisive, transparent, and participatory. Social validation of AI is essential to positively impact and ensure the economic growth of smart cities.

Finally, this study shows the great methodological challenges associated with the constant development of the smart city concept.

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