



SMART CITIES AND URBAN LOGISTICS: A SYSTEMATIC REVIEW OF THE LITERATURE

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Abstract. The concept of smart cities is seen as a key strategy to mitigate the problems generated by the rapid urbanization. Within the smart cities umbrella, the so-called smart mobility has been subject of considerable research. The systematic review reported by this article aimed to identify the most relevant applications supported by smart cities' infrastructure with an impact in urban logistic transports. A total of 39 articles were retrieved, and the results show that the main application areas are related to solid waste management and the routing of logistic fleets, namely, to improve the last mile logistics.

Keywords: smart cities, systematic review, urban logistics, urban mobility.

Introduction

Cities are dominant centres of population and infrastructures. Rapid growth assigns cities a considerable number of challenges, including those related to the urban transport, which is responsible for a significant percentage of the CO₂ emissions with respect to overall transports (Hickman & Banister, 2007; Nocera & Cavallaro, 2014). Moreover, urban transport has a great impact on the

quality of life of inhabitants, due not only to air quality and respective harmful effects, but also to other factors such as the stress caused by the traffic congestion (Downs, 2004). Not surprisingly, the United Nations Sustainable Development aims to tackle these issues by making 'cities inclusive, safe, resilient and sustainable' (UN, 2015).

Following Lu (2014), urban logistics can be defined as all movements of goods, in to, out from, through or within the urban area made by light or heavy vehicles, including also service transport and demolition traffic, shopping trips made by private households and waste. Within this context, cities worldwide have tried to, on the one hand, find alternatives to car usage and increase the use of more sustainable means of urban mobility, including innovative public transports and logistic transports, and, on the other hand, look for solutions which enable transportation linkages, mixed land uses, and high-quality urban services with long-term positive effects on society. Many of the new approaches related to urban services have been based on harnessing technologies helping to create what is labelled as smart cities (Albino, Berardi & Dangelico, 2015; Škultéty, Benová & Gnap, 2021). Such linkage is also at the forefront of research, with the European Union (EU) co-funding and working on several initiatives. An example is the City-VITALity-Sustainability (CIVITAS) initiative, one of the flagship programmes helping the European Commission achieve its ambitious mobility and transport goals, and in turn those in the European Green Deal, with above 800 innovative urban transport measures and solutions in over 80 Living Lab cities that have been implemented across Europe since 2002. Another example can be found in the project Smart Network Operator Platform enabling Shared, Integrated and more Sustainable Urban Freight Logistics (SENATOR), a Horizon-2020 funded project, which focuses on governance schemes for urban planning policies regarding transport, user demand, freight, and logistics planning as well as on city infrastructure.

The concept of smart city encompasses several meanings and overlaps a range of other labels using the city metaphor as a result of growing urbanization processes and develop competences to tackle emerging societal problems. Examples include the intelligent city, the knowledge city, the ubiquitous city, the sustainable city, the digital city, the educating, the responsive city or even the sentient city (Cocchia, 2014; Hoffman, 2020). A brief literature analysis, however, shows that the smart city tag is at forefront of social discourse, policy making and research (Cocchia, 2014; Hoffman, 2020; Nesti, 2020), with several cities globally claiming to be the smartest ones (Abusaada & Elshater, 2020).

One particular feature that characterise smart cities is that they are supported on low-cost sensors capable of collecting vast quantities of data, data-actuated devices and wireless communication networks (Santinha et al., 2019). The collected data are analysed (e.g., advanced data analytic) to promote automate and intelligent processes, to improve the quality of the available services and to promote the emergence of new ones. As such, smart cities promote the integration of traditional urban infrastructures and information technologies (IT), including Internet of Things (IoT) sensors, to allow cities to succeed socially and economically as well as to provide high quality and sustainable urban services. Impacts in different sectors can thus be foreseen (see *inter alia* Lazaroiu & Roscia, 2012), including smart mobility (i.e., local, national, and international accessibility and the availability of communication infrastructure or sustainable and safe transport systems), which has been object of considerable research (Rocha et al., 2020).

Since systematic evidence is essential to inform smart cities' stakeholders and researchers about state-of-the-art solutions, the systematic review reported by the present article aims to examine how literature on smart cities' infrastructure is addressing urban logistic transports, which is a relevant component of smart mobility, and, within the process, to identify the IT applications being used. By providing solid answers to clearly formulated questions using systematic, explicit

and open to scrutiny methods, systematic reviews allow to critically evaluate and synthesize results from multiple primary studies and, accordingly, consolidate knowledge and identify gaps in a given theme (Torgerson, 2005). In this specific case, identifying development paths and recent dynamics within the smart cities trend can provide additional hints for policymaking and scientific research on future possibilities for the provision and governance of urban logistic transports.

The reminder of the article is the following. The next section presents the methodological approach used in this study: the research questions, the search strategy, the inclusion and exclusion criteria, the quality assessment approach used and a synthesis of how results will be reported. The subsequent section reports the results achieved, which is followed by a discussion of the main findings based on the research questions that sustain the study. A brief conclusion is drawn at the end of the article, highlighting the main limitation of the research.

Methods

Research Questions

- The study was informed by the following research questions:
- RQ1: What are the current research trends related to logistics using smart cities' infrastructures?
- RQ2: What types of data are being used?
- RQ3: What are the maturity levels of the solutions being reported?

Search Strategy

Boolean queries were prepared to include all the articles that have in their titles, abstract or keywords a reference to smart city (i.e., one of the following expressions 'Smart City', 'Smartcity', 'Smart-city', 'Smart Cities', 'Smartcities' or 'Smart-cities') together with at least one of the following expressions: 'Logistic', 'Transport', 'Freight facility', or 'Fleet management'. The resources considered to be searched were two general databases, Web of Science and Scopus, and one specific technological database, IEEE Xplore. The literature search was concluded in April 2021.

Inclusion and Exclusion Criteria

As inclusion criteria, the authors aimed to include all the articles that report the development of logistics solutions explicitly using smart cities' infrastructures and that were published until the 31st of December 2020. Considering the exclusion criteria, the authors aimed to exclude all the articles not published in English, without abstract or without access to full text. Furthermore, the authors also aimed to exclude all the articles that report overviews, reviews, or solutions that do not explicitly require smart cities' infrastructures, as well as article reporting studies not relevant for the specific objective of this systematic review.

The selection of the articles was performed in three steps: (i) the authors removed the duplicates, the articles without abstract; (ii) the abstracts of the remainder articles were screened and those not meeting the inclusion criteria were excluded; and (iii) the full texts of the eligible articles were retrieved and screened for inclusion. In turn, the full texts of the included articles were analysed and classified.

In all the steps of the selection and analysis processes the articles were reviewed by at least two authors and any disagreement was discussed and resolved by consensus.

Methodological Quality Assessment

In addition to general inclusion and exclusion criteria, the included studies were assessed against a set of six quality questions, listed in Table 1, which were adopted and adjusted from other studies (Shahin, Liang & Babar, 2014; Yang et al., 2020). Each question was answered according to a binary scale (i.e., 1 for Yes or 0 for No).

Table 1. Study quality assessment questions

#	Study quality assessment questions
Q1	Are the objectives of the study clearly identified?
Q2	Is the context of the study clearly stated?
Q3	Does the research methods support the aims of the study?
Q4	Has the study an adequate description of the technologies being used?
Q5	Is there a clear statement of the findings?
Q6	Are limitations of the study discussed explicitly

Synthesis and Reporting

A synthesis of the studies' characteristics was prepared based on their demographic data. This synthesis comprised: (i) the number of studies published in conference proceedings and in scientific journals; (ii) the distribution of the studies by year and the publication rate, which was calculated using the Root Mean Square (RMS) Least Square Fit; (iii) the number of studies involving multidisciplinary teams; and (iv) the geographical distribution of the studies. It was also considered the institutional affiliation of the first author of each study to determine the number of studies per nation.

The subsequent step was to classify the included primary studies according to their purpose, following a method proposed by Ghapanchi and Aurum (2011), i.e., terms and definitions used in the included articles were identified to create a primary list of application domains, which was afterwards refined by further analyses. This classification was the basis for a narrative description of the studies.

To improve the management logistics, one should be able to collect data from the outside world and to process such data using reasoning and decision-making mechanisms to achieve a correct assessment in order improve service delivery. In the context of smart cities, in addition to data provided by the systems' end users (e.g., couriers), other types of data might be considered, namely data provided by the transportation vehicle (e.g., Global Positioning System coordinates) or data provided by roadside sensors (e.g., vehicle flows). Therefore, a tabular analysis was performed to identify the types of data sources being used by the included studies.

In order to evaluate the maturity of the solutions being reported, the authors distinguished the following development stages: (i) concepts for further development – the study presents a problem and a possible solution (ii) requirements and design – the study included the requirements' elicitation, and a general overview of the application architecture or some of the respective components; (iii) technical testing – the study included results of a performance evaluation of the application or some of its components (e.g., the performance of a specific algorithm); and (iv) pilot testing – the study included a real-world evaluation by end users in their daily context during a certain period.

Results

Study Selection

The flowchart of the systematic review is presented in Figure 1. A total of 10360 articles were retrieved from the initial search on Web of Science (i.e., 2549 article), Scopus (i.e., 4280 articles) and IEEE Xplore (i.e., 3531 articles).

The initial step of the screening phase yielded 6390 articles by removing the duplicates (i.e., 3950 articles) or the articles without abstracts (i.e., 20 articles).

Based on abstracts, 6340 articles were removed since they did not meet the inclusion and exclusion criteria (i.e., they were not published in English, or they are overviews or reviews, editorials, prefaces, and announcements of special issues, workshops or books, they are not related to urban logistics, or although they are related to urban logistics, they do not target solutions to support logistics using smart cities' infrastructures).

Finally, the full texts of the remaining 50 articles were screened and 11 articles were excluded because they did not meet the inclusion criteria. Therefore, 39 articles were considered eligible for this systematic review.

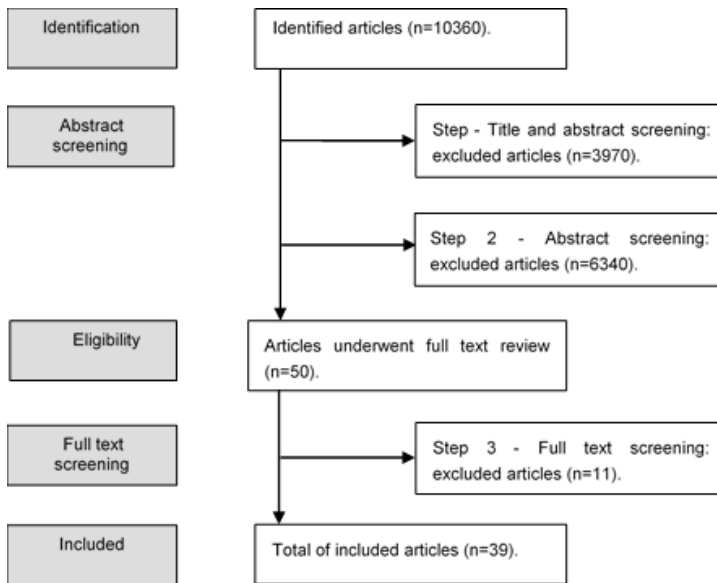


Figure 1. Study flowchart

Demographics of the Included Studies

In terms of publication types, 30 studies were published in conference proceedings and nine studies were published in scientific journals. The included studies were published between 2014 (i.e., two studies) and 2020 (i.e., ten studies). The diagram in Figure 2 exhibits a trend towards an increasing number of publications, since one-third of the studies (i.e., 13 studies) were published in the last two years.

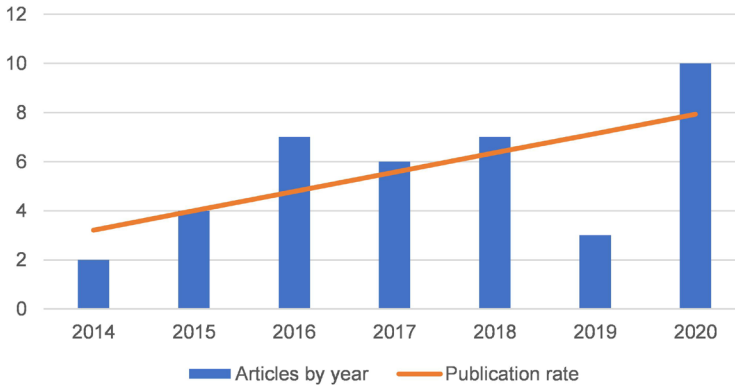


Figure 2. Studies by year and publication rate (calculated using RMS Least Square Fit)

Figure 3 represents the distribution of the included studies by country. Europe and Asia have the highest contribution, with 20 and 15 studies respectively. In turn, North and South America have a relatively residual contribution, with three and only one study, respectively.

Regarding the wide-reaching networks between research institutions, it is possible to observe in Table 2 that only eight studies (i.e., 21% of the included studies) reported on the involvement of multinational teams.



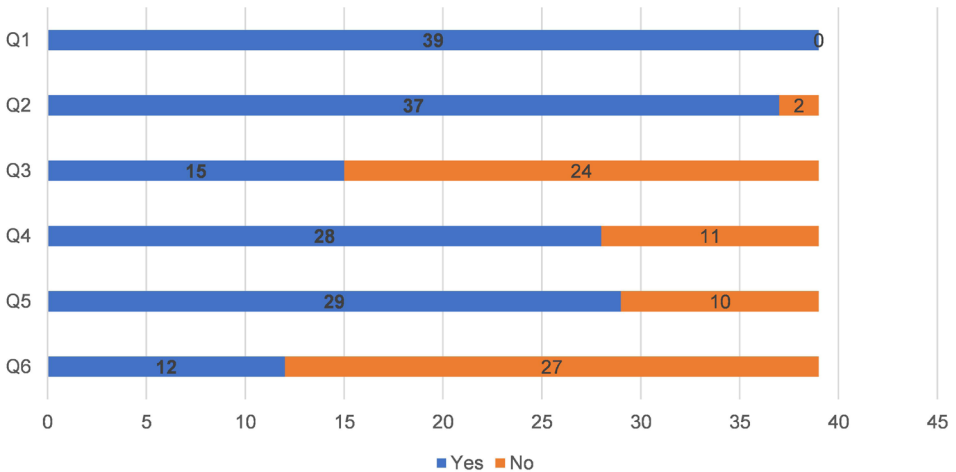
Figure 3. Distribution of the selected studies by country

Table 2. Studies involving multinational research teams

Articles (authors, year)	Countries
(González-Rodríguez et al., 2015)	Spain, Norway, The Netherlands
(Eitzen et al., 2017)	Paraguay, Ecuador, Germany
(Burger et al., 2018)	Germany, New Zealand
(Omara et al., 2018)	Canada, Turkey
(Dolinina et al., 2019)	Russia, Latvia
(Feng et al., 2020)	China, France, Ireland
(Zhang et al., 2020)	China, Australia, Malaysia
(Medehal et al., 2020)	United States, Saudi Arabia

Quality Assessment

The results of the methodological quality assessment of the included studies are present in Figure 4. All thirty-nine studies stated the aims and objectives of the conducted research (Q1). In turn, only fifteen studies explicitly included the methods that supported the research (Q3) and only twelve discussed openly the limitations of their research (Q6). The results for the remainder three questions of the methodological quality assessment varied between 37 (Q2), 28 (Q4) and 29 (Q5).

**Figure 4.** Results of the quality assessment

Purposes of the Studies

All the included articles intend to contribute for digital solutions to support logistic transports using smart cities' infrastructures. However, different categories were identified according to the articles' aims (Table 3): (i) Waste management, (ii) Improvement of the last mile logistics, (iii) Routing of logistic fleets, (iv) Interoperability of the information supporting logistic services, (v) Governance of urban logistics, (vi) Electric vehicles, (vii) Exploitation of surplus food, (viii) Transportation of dangerous goods, (ix) Detection of spatial-temporal events related to logistics and planning, and (x) Emergency mission control. The analysis of the number of studies published by main purpose

throughout time adds valuable insights. On the one hand, waste management and improvement of the last mile logistics are not only the topics with the highest number of publications addressing the issue of urban logistics using smart cities' infrastructures, but have also been the most recent ones, which may show that these are the main concerns in the academia and political arenas. On the other hand, no article has been published since 2016 on the topics of governance of urban logistics, electric vehicles, transportation of dangerous goods, and emergency mission control.

Table 3. Classification of the articles according to categories

Categories	Articles (authors, year and title)
Waste management	<p>Al-Jubori, K., Gazder, U. (2018). Framework for route optimization of solid waste collection.</p> <p>Alwabli, A., Kostanic, I., Malky, S. (2020). Dynamic route optimization for waste collection and monitoring smart bins using ant colony algorithm.</p> <p>Anagnostopoulos, T. et al. (2018). A stochastic multi-agent system for Internet of Things-enabled waste management in smart cities.</p> <p>Bespalov V. et al. (2017) Selection of ecologically efficient and energetically economic engineering-ecological system for municipal solid wastes transportation.</p> <p>Bharathi, R., Banupriya, T., Jayapriyanga, S. (2019). IoT monitory system based smart trash management.</p> <p>Burger, D. et al. (2018). Combining fill-level sensing with route optimization for a more efficient waste collection.</p> <p>Dolinina, O. et al. (2019). Development of semi-adaptive waste collection vehicle routing algorithm for agglomeration and urban settlements.</p> <p>Medehal, A. et al. (2020). Automated smart garbage monitoring system with optimal route generation for collection.</p> <p>Mishra, A., Kumar Ray, A. (2020). IoT cloud-based cyber-physical system for efficient solid waste management in smart cities: a novel cost function based route optimization technique for waste collection vehicles using dustbin sensors and real-time road traffic informatics.</p> <p>Omara, A. et al. (2018). Trajectory-assisted municipal agent Mobility: A sensor-driven smart waste management system.</p> <p>Rosa-Gallardo, D. et al. (2017). Sustainable waste collection (swat): One step towards smart and spotless cities.</p> <p>Saranyadevi, G. (2020). Waste disposal management system for smart city using LoRa.</p> <p>Teja, L. et al. (2018). Smart dustbin based on IOT.</p> <p>Zhang, Qi et al. (2020). An intelligent waste removal system for smarter communities. sustainability.</p>
Improvement of the last mile logistics	<p>Buyukozkan, G., Göçer, F. (2019). Prioritizing the strategies to enhance smart city logistics by intuitionistic fuzzy CODAS.</p> <p>Feng, X. et al. (2021). Crowdsourcing-enabled integrated production and transportation scheduling for smart city logistics.</p> <p>Guerrazzi, E. (2020). Last mile logistics in smart cities: An IT platform for vehicle sharing and routing.</p> <p>Lindawati, C., Wei Cui, N. (2015). Feasibility analysis on collaborative platform for delivery fulfilment in smart city.</p> <p>Lu, M. (2014). Advance logistics for sustainable urban areas.</p> <p>Marciania, M., Cossob, P. (2014). How the URBeLOG project will enable a new governance model for city logistics in Italian metropolitan areas.</p> <p>Navarro et al. (2014). Designing new models for energy efficiency in urban freight transport for smart cities and its application to the Spanish case.</p> <p>Pufahl, L. et al. (2020). Countering congestion: A white-label platform for the last mile parcel delivery.</p> <p>Tu, W. et al. (2020). OCD: Online crowdsourced delivery for on-demand food.</p>

Routing of logistic fleets	Eitzen, H. et al. (2017). A multi-objective two-echelon vehicle routing problem. An urban goods movement approach for smart city logistics. Gutierrez, J. M., Jensen, M., Riaz, T. (2016). Applied graph Theory to real smart city logistic problems. Kumar, R., Rani, C., Kumar, P. (2017). Predicting shortest path for goods delivery to fair price shops in India. Ochoa, A. et al. (2017). Improving transport optimization to smart city's competitiveness. Reyes-Rubiano, L. et al. (2017). A simheuristic approach for freight transportation in smart cities.
Interoperability of the information supporting logistic services	Lopez-Martin, A., Carvajal, R. and Cortes, P. (2016). Smart ecosystem for a sustainable, safe and integrated freight transport. Vennesland, A., and Dalmolen, S. (2015). A common language for logistics services interoperability. Zhang, B. (2018). Service-oriented logistics supply chain information management system.
Governance of urban logistics	Lindawati, G., Souza, R. (2016). Determining urban freight facility locations using post-evaluation deliberation. Schröder, S., Dabidian, P., Liedtke, G. (2015). A conceptual proposal for an expert system to analyze smart policy options for urban CEP transports.
Electric vehicles	Schau, V. et al. (2016). Intelligent infrastructure for last-mile and short-distance freight transportation with electric vehicles in the domain of smart city logistic. Schau, V. et al. (2015). Smart City Logistik Erfurt (SCL): ICT-support for managing Fully electric vehicles in the domain of inner city freight traffic.
Exploitation of surplus food	Scazzoli, D. et al. (2019). SIVEQ: An integrated system for the valorization of surplus food.
Transportation of dangerous goods	Adamec, V., Schüllerová, B., Adam, V. (2016). Issues of hazardous materials transport and possibilities of safety measures in the concept of smart cities.
Detection of spatial-temporal events related to logistics and planning	Suma, S. et al. (2017). Enabling next generation logistics and planning for smarter societies.
Emergency mission control	Polo, A. et al. (2016). Optimization strategies for fleet management based on wireless terminals localization in smart cities scenarios.

(i) Waste Management

Waste management is the category with the highest number of articles (i.e., 14 articles). The set of articles mirrors the challenges faced by smart cities when managing waste collection, transport, disposal and treatment and acknowledges the economic, health and environmental impacts of waste. It also affirms the high relevance of the IoT as a pervasive component of any waste management systems in smart cities.

Anagnostopoulos et al. (2018) address the role played by the IoT in waste management. Based on experiments held in the (smart) city of Saint Petersburg, Russia, the authors claim that the system enables policymakers to improve the allocation of collection trucks in the smart city and enhances traffic prediction capabilities and thus the planning of waste management tracks. Saranyadevi (2020) also intends to give an IoT-based building solution for the issues looked at by current waste means. With the proposed methodology, an optimized route is calculated and notified to the officials, which enable them to empty the filled bins at a short span of time. In the same line of thought, Burger, Weiß, Sarkar, Kirsch and Dünneberger (2018) propose a solution for optimising waste collection operations. The solution feasibility was tested in the German city of Regensburg, involving biological waste and more than 800 waste containers. The experiment results give rise to

improvement recommendations in terms of waste collection routes, whose implementation has already granted benefits to Regensburg city council. Teja, Muthaharunnisa, Bharathi and Krishna (2018) take a very similar approach, although focusing exclusively on the smart waste bin components. The authors describe the devices and software that make possible to remotely monitor the level of disposed waste materials in each waste bin. Focusing also on waste collection, Alwabli, Kostanic and Malky (2020) introduce a mechanism in Alawali District, Mecca, where bins can be monitored, and the level of wastes checked in real-time reduces the necessity of having to visit bins that are empty or half-filled.

Acknowledging the need for effective and efficient decision-making systems in smart cities' waste management, Omara, Gulen, Kantarci and Oktug (2018) propose a smart waste management solution driven by a Wireless Sensor Network (WSN). As such, they develop a heuristic method for planning waste collection routes, using a WSN able to raise a set of alarms to initiate/trigger waste collection. The research presented by Dolinina, Pechenkin, Gubin, Aizups and Kuzmin (2019), on the other hand, uses the IoT and smart measuring devices to create a waste collection tool and promote its integration in a smart city environment. The authors claim that Intelligent Transport Systems (ITS) allow making efficient routing and avoid traffic congestion. Tested in Saratov (Russia), the proposed approach allows to reduce the empty run of garbage trucks, to increase the weight and volume of garbage taken out.

The aim of the study developed by Bepalov, Paramonova, Gurova and Samarskaya (2017) is to contribute to the improvement of the system of solid municipal wastes handling, including transportation as one of the major stages. This work demonstrates that is possible to provide ecological safety on certain parts of urban territories by preventing losses while increasing efficiency and economy of transportation. Al-Jubori and Gazder (2018) also develop a framework to plan and establish optimised municipal solid waste transportation routes in Bahrain. Aiming at minimising travel distance and duration, as well as waste collection and social costs, the authors use traffic situation, road alignment, bin/compactor location and sizes as primary input parameters. More recently, the study presented by Mishra and Kumar Ray (2020) aimed to propose a route optimisation technique based on a novel cost function for a Waste Collection Vehicles (WCV). The real-world implementation of the proposed route optimization technique was validated using real-time data in Bhubaneswar, a smart city in the province of Odisha, India.

The fact that the conventional method of manually monitoring the wastes in waste bins is a tiresome process with absurd human efforts, time and cost, which can easily be avoided, was the argument presented by Medehal, Annaluru, Bandyopadhyay and Chandar (2020) to develop their study. For this, the authors propose the tools of IoT to completely automate the process of garbage monitoring and provide an optimal route for garbage collection. An intelligent urban waste removal system is also presented by Zhang, Li, Wan, Skitmore and Sun (2020). With a background of data management, the entire process of intelligent automatic waste removal is triggered by automatic communication from individual waste bins to a WCV where the bin needs to be emptied, and the automatic collection and transportation by the WCV in response. In order to verify the feasibility of the system, a closed park in Guangzhou, China, was selected for simulation and testing.

The research reported by Rosa-Gallardo, Ortiz, Boubeta-Puig and García-de-Prado (2017) reveals a hardware architecture and a software architecture aimed at monitoring waste containers and providing real time information about their condition. Four critical situations are contemplated by the proposed Sustainable Waste Collection (SWAT), namely, the occurrence of dust, fire, lack of energy to maintain the container hardware functioning properly, and container lid blockage. In turn, Bharathi, Banupriya and Jeyapriyanga (2019) propose the development of a Smartbin.

In this sense, the authors propose a model to screen the trash level of the particular trash receptacles progressively and to distinguish the level when the edge worth is come to by consolidating sensors and Raspberry Pi. When a truck is filled in, a message is received to clean the bin. This scheme eliminates the present status of the bins often deposited without being washed.

(ii) Improvement of the Last Mile Logistics

Nine articles focus on the improvement of the last mile logistics, the second most addressed topic. In more conceptual terms, the work of Buyukozkan and Göçer (2019) was about understanding the priority of the strategies to improve smart city logistics. The importance of each criterion was estimated using Intuitionistic Fuzzy logic, and the priority was computed using Combinative Distance based Assessment. As for Marciania and Cossub (2014), the authors describe the status of the project Urban Electronic Logistics (URBeLOG) whose general objective is to develop and trial a distributed IT environment, hosted in an open, dynamic and participated computerized platform of services and applications for last mile urban logistics. The idea is to aggregate the ecosystem of stakeholders and manage complete distribution processes in real time. Also integrating a project – SMart green Innovative urban Logistics Models for Energy efficient Mediterranean cities project (SMILE) – Navarro, Roca-Riu, Furió and Estrada (2014) show the results of the live test of smart cities' urban logistics solutions in the Spanish cities of Barcelona and Valencia, which consisted of combining electric tri-cycles with transshipment terminals for the last-mile delivery of parcels and small shipments. Integrating as well the SMILE Project, Pufahl et al. (2020) propose a white label approach to the last mile parcel delivery process. The main goal is to make the last stage of parcel delivery more flexible for reducing traffic congestion while maintaining an improved client service. The authors elaborate on the conceptual architecture of the desired platform and discuss a pilot study ran for six months in a German city.

With the drive to improve the efficiency of last mile logistics by consolidating delivery demands and reducing the number of trucks needed, Lindawati and Wei Cui (2015) propose a platform, the virtual consolidation centre, to encourage collaboration among stakeholders with minimum information sharing to protect their competitive intelligence. To evaluate the feasibility of the platform traffic congestion and shopping mall operations were observed in three areas in Singapore. In turn, the study published by Lu (2014) presents some good practices of applications in the field of urban freight transport in several European logistics clusters. The aim is to reinforce the importance of developing solutions to collaborate, consolidate and coordinate (cross-chain control) in supply chain and freight operations to create a systematic approach for the improvement of urban communities.

Some works focused crowdsource enabled solutions. Feng, Chu, Chu and Huang (2021) propose an algorithm to compute the transportation schedule in a scenario with crowdsource enabled integrated production and transportation scheduling. According to the authors, crowdsourcing delivery usually allows a more personalised service, and it is cost-effective as relies on using existent transport tools of crowdsource thus reducing investment costs and diesel-powered truck pollution. Guerrazzi (2020) also proposes a crowdsource enabled platform despite never using that term. Unlike Feng et al. (2021), Guerrazzi focus on the platform architecture and not on the optimization component. The proposed platform was developed under the project Support of Integrated Interoperability for Services to Citizens and Public Administration (Sii-Mobility), and it is based on four main modules: extract transform load, optimizer, web application, and map display. Tu et al. (2020), on the other hand, tackle the challenge of computing optimal real-time routing in a crowdsource enabled solution for on-demand food delivery. It is proposed a hybrid meta-heuristic algorithm composed by adaptive a large neighbourhood search and a tabu search.

(iii) Routing of Logistics Fleets

Five articles are dedicated to challenges of routing of logistics fleets. Four of them focus on improving logistics traffic routes (Eitzen, Lopez-Pires, Baran, Sandoya & Chicaiza, 2017; Kumar, Rani & Kumar, 2017; Ochoa, Larios, Maciel & Mora, 2017; Reyes-Rubiano, Faulin, Calvet & Juan, 2017) and one intends to plan routes for assessing the quality of a communication infrastructure across a large territory (Gutierrez, Jensen & Riaz, 2016). All the articles regarding the improvement of logistics traffic routes proposed algorithms in which the performance was evaluated using computer simulation.

The study of Gutierrez, Jensen and Riaz (2016) was about planning routes for two vehicles guaranteeing 100% coverage of 19,000 km of roads in North Jutland Region (Denmark) while minimizing route repetition. The vehicles were fitted with mobile broadband instruments for assessing the quality of the communication infrastructure across this territory. Kumar et al. (2016), on the other hand, designed a smart system for delivering goods to FairPrice shops. For the case, the FairPrice shops are just destination points like the unloading points in the study published by Eitzen et al. (2017). They have used the well-known Dijkstra algorithm with MapReduce over Hadoop to speedup data processing.

Three articles (Eitzen et al., 2017; Ochoa et al., 2017; Reyes-Rubiano et al., 2017) address the routing problem as a vehicle routing issue or a variant of it. This means that these three articles tackle a much more difficult problem than the one addressed by Kumar et al. (2016). This also enables the use of richer data such as geographic information that includes city roads and points of loading and unloading cargo, but good heuristics or assumptions are necessary so that solutions can be achieved in reasonable computing time. Additionally, Eitzen et al. (2017) report the test of two examples of application, Ochoa et al. (2017) report computer experiments for a simulated scenario of Cuernecava metropolitan area (Mexico), and Reyes-Rubiano et al. (2017) compare their approach with previous published works testing with up to 60 customers (unloading area) and nine depots (loading area). However, the proposals need to be validated in concrete real situations.

(iv) Interoperability of the Information Supporting Logistic Services

The three articles that fall into the thematic field of interoperability differ in nature and scope, although pursuing technological improvements in logistics. Acknowledging the relevance of IT to solve problems affecting freight multimodal transport, such as inefficiency, high costs and environmental impact, Lopez-Martin, Carvajal and Cortes, (2016) report the achievements of a research project regarding the provision of a smart solution for inter-modal container handling, based on integrated micro sensors and low-cost energy-autonomous WSN. In turn, Vennesland and Dalmolen (2015) depart from the need to endow transport logistics with agile business networks and thus dynamic and flexible information systems, to argue for the relevance of a common language to semantically match different information standards used in the logistics world. The authors identify a hand full of major challenges to be tackled and to solve them they proposed an ontology supported on a common framework for IT in the domain of transport and logistics. Trying to go beyond traditional methods of transmitting information, Zhang (2018) presents a solution scheme for rapid, accurate and low-cost information exchange among supply chain enterprises during logistics business operation. Accordingly, the author develops a public logistics supply chain information exchange platform that uses a heterogeneous data exchange engine and data exchange agent to realize end-to-end data exchange of heterogeneous information system in supply chain enterprises and zero-development access.

(v) Governance of Urban Logistics

Two articles were classified as governance of urban logistics. Schröder, Dabidian and Liedtke (2015) propose a conceptual framework to analyse smart policy options. Held in Berlin, one of the major conclusions of the study is that adding actors and activities to an existing passenger scenario makes possible to analyse the effects of various policy measures, such as the introduction of dedicated parking space. In turn, Lindawati and Souza (2016) propose a tool to support decision makers' choice of suitable locations for freight storage facilities. The tool, simulated for a case study (Singapore), provides the flexibility to tighten or loosen certain resources/constraints to determine urban consolidation centre for urban retail clusters.

(vi) Electric Vehicles

Only two articles refer to electric vehicles and, more specifically, to IT solutions directed at mitigating the problems inherent to limited driving range. Schau et al. (2015) present the preliminary results of a research and development project, the Smart City Logistik Erfurt, directed at improving the conditions to hoist the utilization of electric vehicles in the country. By combining dynamic range prediction with smart route planning tools, the authors develop an IT based system to support the logistics of short distance freight operations using a fleet of small and medium electric vehicles. Using data from the same project, the following year, Schau et al. (2016) update information on the architecture underpinning the IT system and the driving range estimation model, which associates data on drivers, vehicles, orders, shipments, charging stations, users, companies and customers. Two prototypes have been tested by drivers and dispatchers. In the end, the positive characteristics of both prototypes have been considered to develop a fully functional system.

(vii) Exploitation of Surplus Food

Only one article was included in this specific category. Overall, Scazzoli et al. (2019) present a system named Sistema Integrato per la Valorizzazione delle Eccedenze Alimentari nel Quartiere (SIVEQ) for improving the exploitation of surplus food for social reuse by Non-Profit Organizations. The system integrates IoT technologies for data collection and Big Data Analytics for improving the efficacy of food surplus reuse and, according to the authors, is ready for real world operation.

(viii) Transportation of Dangerous Goods

Under this category, Adamec, Schüllerová and Adam (2016) introduce the issue of risks associated with the transportation of dangerous goods in cities and propose measures adequate to smart cities. One possible measure is the identification and monitoring of carriage of dangerous goods vehicles in the city, or in proximity or arriving and moving there, using existing Closed-Circuit Television (CCTV) systems. Another option is automatic vehicle identification, as well as automatic identification of license plates. The opportunity is not only to improve the communication between drivers and emergency services but also the possibility of using green energy, which can be used in both the proposed measures.

(ix) Detection of Spatial-temporal Events related to Logistics and Planning

On their work on the use of social media for the recognition of spatial-temporal events linked to logistics and planning, Suma, Mehmood, Albugami, Katib and Albeshri (2017) applied big data and artificial intelligence tools to study twitter data about London. Moreover, Google Maps Geocoding was used to locate the tweeters and make additional analysis. The authors found and located

congestion around London, also discovering that, during a certain period, top third tweeted words were about job and hiring, leading them to locate the source of the tweets which happened to be originating from around the United Kingdom major financial centre.

(x) Emergency Mission Control

On this topic, Polo et al. (2016) propose a full-scale decision support system prototype for the emergency mission control that aims to provide operators with updated, reliable, and punctual information. The idea is to identify how many and which assets shall be deployed for the given mission considering three objectives: (i) maximize the utility of the selected assets; (ii) minimize the dispatch time; and (iii) minimize the cost of moving assets from its currently assigned location. To experimentally validate the proposed assisted selection strategy in a real scenario, the idea has been implemented in an interactive tool whose prototype was being validated in several Italian emergency agencies.

Data Sources

Table 4 presents the different types of data sources referred by the included studies. The majority of the studies (i.e., 19 studies) do not refer data sources, since they are focused on the formulation of specific algorithms and in terms of data inputs, they considered high-level abstractions or data generated randomly. In turn, 11 studies refer the use of roadside data, such as data from sensing devices installed in dustbins, weather conditions sensors, or data from sensors aiming to determine vehicles flows or parking availability. In three of these 11 studies, roadside data are used together with other data sources (e.g., vehicles data sources).

Table 4. Data sources being used by the included studies according to categories

Articles (authors, year)	Couriers	Vehicles	Roadside	Other data sources	No data sources
Waste management					
(Bespalov et al., 2017)					x
(Anagnosto et al., 2018)					x
(Burger et al., 2018)			x		
(Gazder et al., 2018)			x		
(Teja et al., 2018)			x		
(Rosa-Gallardo et al., 2018)			x		
(Omara et al., 2018)					x
(Dolinina et al., 2019)		x			
(Bharathi et al., 2019)			x		
(Zhang et al., 2020)					x
(Medehal et al., 2020)		x	x		
(Malky et al., 2020)			x		
(Mishra et al., 2020)			x		
(Saranyadevi et al., 2020)			x		
Improvement of the last mile logistics					
(Lu, 2014)					x
(Marciani et al., 2014)	x	x	x		
(Lindawati et al., 2015)					x
(Navarro et al., 2016)					x

Articles (authors, year)	Couriers	Vehicles	Roadside	Other data sources	No data sources
(Büyüközkan et al., 2019)					x
(Pufahl et al., 2020)					x
(Feng et al., 2020)					x
(Guerrazzi, 2020)	x				
(Tu et al., 2020)	x				
Routing of logistic fleets					
(Gutierrez et al., 2016)		x			
(Eitzen et al., 2017)					x
(Kumar et al., 2017)					x
(Ochoa et al., 2017)					x
(Reyes-Rubiano, 2017)					x
Interoperability of the information supporting logistic services					
(González-Rodríguez et al., 2015)					x
(Lopez-Martin et al., 2016)					x
(Zhang, 2018)				Consumers, retailers and suppliers	
Governance of urban logistics					
(Schröder et al., 2015)					x
(Lindawati et al., 2016)					x
Electric vehicles					
(Schau et al., 2015)	x	x			
(Schau et al., 2016)	x	x			
Exploitation of surplus food					
(Verticale et al., 2019)				Donors and non-profit organizations	
Transportation of dangerous goods					
(Adamec et al., 2016)					x
Detection of spatial-temporal events related to logistics and planning					
(Suma et al., 2017)				Big data such as twitter streaming	
Emergency mission control					
(Polo et al., 2016)		x	x		

In terms of vehicle data sources, the localization of the vehicles is considered by seven studies. In addition, one of these seven studies, present an architecture of sensing devices that might be integrated in containers to determine the cargo integrity (e.g., environmental parameters such as pressure, humidity, temperature, or light intensity). In four studies, data provided by the couriers are used for the logistic management. Finally, three studies considered other data sources: data provided by donors and non-profit organizations are used for the management of surplus food, data from consumers, retailers and suppliers are used to optimize the delivering services, and big data are being used to detect spatial-temporal events that might impact the logistics and planning.

One important aspect retrieved from Table 4 is the fact that different data sources are seldom used together. Just five refer the use of different data sources: couriers, vehicles and roadside data sources – one study (Marciani & Cossu, 2014); vehicles and roadside data sources – two studies (Polo et al., 2016; Medehal et al., 2020); couriers vehicles data sources – two studies (Schau, Rossak, Hampel & Späthe, 2015; Schau et al., 2016).

Maturity Level

Concerning the maturity level of the included studies (Table 5), one study was classified as a concept for further development, 15 studies were classified as requirements' elicitation and design, 16 studies focused on the technical testing, and seven studies include a live test of urban logistic solution.

In the paper published by Adamec et al. (2016), the authors only address concepts for further development, proposing a basic methodology approach to identify and analyse risks, which can be incorporated into the functional systems in the cities.

In turn, in the overall 15 articles report on requirements elicitation or systems architecture there is no explicit information regarding the next steps foreseen by the authors. Lindawati and Souza (2016) argue that the idea is to consolidate the proposal and to later put forth real life experiences.

On the other hand, in terms of technical testing, proof-of-concept or prototypes, different approaches (e.g., simulation decision models, tools/platforms to support decisions) were used to validate the proposals.

Finally, in what concerns the live tests in urban logistic solutions, Navarro et al. (2016) perform a real-life scenario in the Spanish cities of Barcelona and Valencia, combining the use of electric tricycles and transshipment terminals for the last-mile delivery of parcels and small shipments. Polo et al. (2016), in turn, propose and validate in an Italian province a full-scale decision support system prototype for the emergency mission control. In both cases, the authors underline the valuable results obtained and the need for further testing. Moreover, Pufahl et al. (2020) conduct a pilot study for six months in a German city of 300k inhabitants, Anagnostopoulos et al. (2018) validated their system on an experiment held in the Saint Petersburg (Russia), Burger et al. (2018) tested their solution in the German city of Regensburg, involving biological waste and more than 800 waste containers, the system proposed by Dolinina et al. (2019) has been tested in Saratov (Russia), with results showing a 21% decrease in the processing time of containers compared to traditional manual planning and, finally, Alwabli et al. (2020) conducted an experiment in Alawali District in Mecca with 52 waste collection points.

Table 5. Maturity level of the proposed solutions.

Maturity Level	References
Concepts for further development	Adamec et al., 2016
Requirements' elicitation and design	Lu, 2014; Marciani & Cossu, 2014; Schau et al., 2015; Schröder et al., 2015; Lopez-Martin et al., 2016; Bepalov et al., 2017; Suma et al., 2017; Rosa-Gallardo et al., 2017; Al-Jubori & Gazder, 2018; Teja et al., 2018; Zhang, 2018; Bharathi et al., 2019; Guerrazzi, 2020; Medehal et al., 2020; Saranyadevi, 2020
Technical testing	Lindawati & Wei Cui, 2015; Vennesland & Dalmolen, 2015; Lindawati & Souza, 2016; Gutierrez et al., 2016; Schau et al., 2016; Reyes-Rubiano et al., 2017; Eitzen et al., 2017; Kumar et al., 2017; Ochoa et al., 2017; Omara et al., 2018; Buyukozkan & Göçer, 2019; Scazzoli et al., 2019; Feng et al., 2020; Mishra & Kumar Ray, 2020; Tu et al., 2020; Zhang et al., 2020
Pilot testing	Navarro et al., 2016; Polo et al., 2016; Putahl et al., 2018; Anagnostopoulos et al., 2018; Burger et al., 2018; Dolinina et al., 2019; Alwabli et al., 2020

Discussion

The results of our review bode well for urban logistics supported in smart cities infrastructures research. Our analysis reveals several additional noteworthy findings.

First, there is a growing trend of interest in this field of research, which is reflected in the increasing number of publications over the last years. A majority of the studies was performed by researchers affiliated at Institutions based in Europe, which is a predictable result, as the European Commission proposed several initiatives EU-funded SMILE and URBeLOG projects or, more recently, H2020 CIVITAS living labs' projects and H2020 Urban Logistics as an on-Demand Service (ULaaDS) project.

With the world more interconnected than ever before, so is academic research becoming more international. Researchers are reaching out to their colleagues around the world and, accordingly, the prevalence of global teams in international organizations is rapidly rising (Mockaitis, Zander & Cieri, 2020). Bearing this in mind, only eight studies (i.e., 21% of the included studies) reported on the involvement of multinational research teams. Surprisingly, only two studies (González-Rodrigues, Vennesland & Dalmolen, 2015; Burger et al., 2018) were conducted by multidisciplinary teams of the EU, which suggests that the existing European programmes, in the specific topic of this systematic review, are not being succeeded to create synergies between researchers based at different countries.

With reference to the first research question (i.e., the current research trends related to logistics using smart cities' infrastructures), the results show that the main application areas are related to the management of solid waste in smart cities, the studied problem of 14 of the retrieved studies, and the routing of logistic vehicles, namely in terms of last mile logistic. Interestingly, these are also the topics in which there has been a growing interest in research.

For more than the half of the studies related to waste management, the major issue is the optimization of the routes of wireless multi-functional vehicles. The rest of the studies, on the other hand, aimed to taking advantage of the monitoring of the waste bins, namely using WSN. In turn, the routing of logistic fleets in general is studied by five studies, while the routing of last mile logistic vehicles is the problem faced by nine of the studies.

Regarding the second research question (i.e., types of data that are being used) there are some aspects that should be highlighted in this discussion. In addition to the fact that a significant proportion of the articles (i.e., 19 studies) do not mention the data sources, the studies that do mention them show great heterogeneity not being able to ascertain a common ground. Few applications (i.e., five studies) were found to use more than one type of data sources and even within a given area the types of data sources diverge among themselves. Therefore, the results suggest that one is still searching for the resources that can and should be used, and an integrated and consolidated vision on this matter seems to be lacking. Inclusively, it should be noted that, despite the opportunities offered around the smart cities concept, specifically the possibility of collecting data from various sources, so that these can be used to manage resources and assets more efficiently, there seem to be applications that effectively do not make use of smart cities infrastructures.

Finally, concerning the third research question (i.e., the maturity level of the applications being reported), the included articles report: (i) concepts for further development; (ii) requirements elicitation and design; (iii) technical testing; and (iv) pilot testing.

Developing new technologies or new approaches to existing means involves creating something that did not exist before to improve the current *status quo*. In the concept development phase, initial alternatives are usually generated and the technological systems with greater poten-

tial for success for later development are selected (Naveiro & Oliveira, 2018). This is the case of the study published by Adamec et al. (2016), in which a basic methodology approach to identify and analyse risks regarding cities' functional systems is proposed.

Effective requirements elicitation, the next maturity level, is perceived to be one of the most crucial activities in technological development projects. The rationale is that solely a deep understanding of user needs and requirements will result in a desirable solution with features that satisfy customers and users alike (Hehn & Uebernickel, 2018). In the present review, 15 studies report on requirements elicitation or systems architecture.

On the other hand, 16 articles present proof-of-concept or prototypes, representing a step forward in technological maturity. Though the technological proposals (e.g., simulation decision models, tools/platforms to support decisions) and their purpose differ, it is worth mentioning that the studies included in the routing of logistic fleets category are within this type of maturity level. In most cases, however, the authors do mention the need to go further and test it in real life scenarios.

Seven articles describe a live test in urban logistic solutions. In this major step increase in maturity level, technology has been proven to work in its final form and under projected conditions. The range of localities used for real-life scenario varied considerably, but interestingly were seen mainly on European cities, such as the Spanish cities of Barcelona and Valencia, Regensburg and an anonymous medium-sized German city, and Saint Petersburg and Saratov from Russia.

Conclusion

The systematic review reported by this article aimed to analyse how literature on smart cities' infrastructure is addressing urban logistic transports and to identify the IT applications used within the process. Thirty-nine articles were retrieved, covering different purposes. Largely, waste management and improvement of the last mile logistics are the domains with the highest number of publications addressing the issue at stake. They have also been the most recent ones, from 2017 onwards, which may indicate that these are the main concerns in the academia and political arenas.

It is worth mentioning that, although the review selection and the data extraction of this systematic review were rigorous, it should be acknowledged that this study has limitations, namely the dependency on the keywords and the selected databases, or the fact that both grey literature and publications written in other languages than English were excluded. Still, this systematic review allowed to collect relevant evidence on smart cities and urban logistics and enhance our understanding on the current research trends, the types of data used and the maturity levels of the solutions being reported. For those in academia or in the policy-making arena interested to know what is being done within this topic under the smart cities umbrella, may find its reading useful.

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