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Managing last-mile urban freight transport through emerging information and communication technologies: a systemic literature review

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Abstract

Up-to-today, urban logistics has shown significant relevance around the world because of the numerous problems due to the increase in freight flows in the cities driven by the changes occurring, e.g., smaller and more frequent deliveries. The irreversibility of these processes is pushing researchers to look for theoretical and practical approaches to address changes to improve sustainability. Therefore, the need to develop new methods and models to govern urban freight transport are emerging and the evolution of information and communication technologies (ICT) have opened the road to develop and implement new advanced approaches to manage sustainable urban last-mile freight transport. In particular, they are mainly devoted to support traffic management and control, and land planning through the integrated use of ICT, which allows one to optimise freight traffic by collaborating fleet management, advanced urban supply chain integration, and so on. In order to capture the current state of research and to identify the future challenges, a systemic review is presented.

Keywords: last mile, e-ICT, delivery system, crowdshipping, multi-echelon distribution system, city logistics, collaboration, coordination, systemic review

1. Introduction

Last mile delivery, namely "*a series of activities and processes that are necessary for the delivery process from the last transit point to the final drop point of the delivery chain*" (Yuen et al., 2018), is an important task of urban freight transport and logistics (UFT). Besides, UFT questions are gaining popularity given that it plays a key role in satisfying the users' needs (e.g., citizens, visitors, employees - city users), but on the other hand, it is responsible of significant impacts (Russo and Comi, 2023). An increasing number of researchers are working to improve the quality of delivery (e.g., delivery punctuality and time reliability, parcel tracking, pick up lockers, etc.; Masteguim and Cunha, 2022; Perski et al., 2022; Russo and Comi, 2020)

The changes occurring in delivery operations affect the sustainability and liveability of cities. In recent years,

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Information and Communication Technologies (ICT), as well as the Intelligent Transport Systems (ITS), have become more popular. They support planners and stakeholders, in general, to make supply-chain processes more sustainable and effective. Various approaches are being developed to introduce innovative technologies into UFT (Comi and Russo, 2022). This allows planners to assess the situation in real time and organise deliveries taking into account criteria used by stakeholders.

In fact, recently, the evolution of emerging information and communication technologies (e-ICT) has opened the road to develop and implement new integrated and dynamic City Logistics (CL) solutions (Russo and Comi, 2021; Schroten et al., 2020), to improve the level and the quality of life of city users (e.g., residents, visitors). In particular, telematics can support the effectiveness of each action that can be implemented to foster the sustainability and liveability of the urban area as shown by the recent works on such a field (Comi and Russo, 2022; Green et al., 2022). Last-mile operations are facing new and uncertain trends such as: small and frequent shop deliveries (due to limited availability of retail store surfaces in the inner areas due to high rent costs and just-in-time policies), e-commerce and omni-channel retailing, new way to deliver products to customers (e.g., express delivery, same-day delivery, as well as instant-deliveries). On the other hand, urban planners and researchers are looking at policies that can limit the impacts due to such changes (e.g., reduction of number of freight vehicles, and of travelled kilometres, optimization of e-deliveries). In this context, some of the more promising measures to implement can involve collaboration and sharing of resources among actors involved in the process, the optimization of vehicle loads and of the last-mile transport as well as optimization of e-deliveries solving the large number of parcels to deliveries and delivery failure due to the absence of receivers. Telematics and, in particular, e-ICTs as shown by the recent works on such a field (Comi and Russo, 2022; Green et al., 2022) can offer valuable opportunities, including the security of data through the use of block chain. These innovations are discussed in more detail below.

e-ICTs, optimized to develop transport systems, are thus the real advanced intelligent transport systems (ITS), which are useful for establishing a new generation of city logistics systems to support goods operations. Although such technologies have been quite largely used in other economic sectors, they can be considered quite new and emerging for CL (Cagliano et al., 2020; De Oliveira et al., 2021; Taniguchi et al., 2020). The edges need to be defined with respect to the studied topics of city logistics. It is also necessary to identify some classes of new ICTs that present homogeneity with respect to the investigated topics.

Many researchers have investigated technology challenges, however, each of them is described as a separate system (Gomez-Marin et al., 2020; Hu et al., 2019; Jie et al., 2019). The use of ICT has not yet reached widespread use. This paper aims to emphasize the use of e-ICT in a large, shared and integrated way. Such an integration could push towards new and promising results. For example, when considering its use in the urban logistics system, the Internet of Things technology can be applied to consider the purchase of goods by customers as information, e.g., providing its availability in the outlet stock. It can be also used to forecast future end consumers' demand. Besides, this information about goods, deliveries, stakeholders, etc. can form a large database. Since it has different attributes and characteristics, and the size of such an information can be very large, it can be considered as a Big Data.

Also, for better forecasting the impacts and effects of the functioning of the system, Digital Twin technology has been developed. Thus, it is possible to see how the system will change when some parameters are changed (adding time windows/closed zones, etc.) or introducing restrictions (vehicles up to 3 tons). Finally, adding Artificial Intelligence, the system could become autonomous and/or tools can be set up for supporting decision-making in last mile.

The paper is organized as follows. Section 2 overviews e-ICT and discusses its contribution to improve last-mile operations, while Section 3 describes the methodology developed for the systemic literature review. Section 4 discusses the results of the systemic review, and finally, Section 5 draws conclusions and discusses future challenges.

2. e-ICTs and last-mile deliveries

2.1. Authoritative policy

Although, there is a growing interest towards freight mobility from a local administration point of view, only recently cities have been pushed to take into due to consideration the effects of urban goods movements on the city liveability and sustainability. Besides, to solve the relevant lack of sustainability goals in city planning, the United Nations promoted Agenda 2030 (Comi et al., 2023; Ruiz-Mallén and Heras, 2020) and identified 17 Sustainable Development Goals (SDG). SDG 11 (*make cities and human settlements inclusive, safe, resilient and sustainable*) refers to cities. In this context, the European Commission has promoted the concept of sustainable urban mobility and has supported guidelines for developing Sustainable Urban Mobility Plans (SUMP; SUMP, 2019). According to the SUMP approach, the guidelines for developing and implementing Sustainable Urban Logistics Plans (SULP) were defined

within the research project named ENCLOSE (Energy Efficiency in city logistics services for small and mid-sized European historic towns; Ambrosino et al., 2015).

Besides, the European Union (EU) Commission is developing the Horizon programmes. This is the EU's key programme for research and innovation. It tackles climate change, helps to achieve the UN Sustainable Development Goals and boosts competitiveness and growth. Several projects have been funded within this research (CINEA, 2022). Since 2002, the CIVITAS Initiative has been working to make sustainable and smart urban mobility a reality for all in Europe and beyond. Projects are being developed to improve many cities. The Sustainable Urban Logistics Planning To Enhance Regional freight transport (SULPiTER, Comi et al., 2020) project focused on the design of sustainable urban logistics. Local administrators, researchers, and urban logistics planners are involved. A Logistics Sustainable Index methodology has also been developed. It is applied to provide an impact assessment of proposed initiatives. In an attempt to reduce emissions and therefore improve the liveability of cities, some 200 low-emission zones (LEZs) have been created. This policy implies restrictions on vehicle access to urban zones based on an emission standard. In this context, the definition of future scenarios, which merge and integrate the different CL measures implemented to improve city liveability and sustainability, could benefit by the opportunities offered by the e-ICTs, as discussed below.

2.2. The considered information and communication technologies

Below, the investigation of technologies that involve transport, but that refer to the characteristics of vehicles is out of the scope of this study. Additionally, the automotive industry is developing autonomous vehicles for UFT, and autonomous solutions have been tested for last-mile delivery in urban and rural areas. However, they represent the future development of last-mile transport, and currently, they are at the prototype stage, therefore, they are not considered below. Then, reviewing the scientific and technological literature, the field of investigation is restricted to ICTs that directly impact urban transport. It is thus possible to identify four main classes of technologies that push towards a smart CL: Internet of Things (IoT); Big Data (BD); Block Chain (BC); Artificial Intelligence (AI). Readers can refer to Comi and Russo (2022) for more details.

Such technologies can improve the dynamic freight management of CL. For example, referring to the opportunities offered in improving the operations by transport and logistics operators, Navigation Systems (NS) can be developed to provide specific route guidance using information about traffic regulations (e.g., road works, lane directions). Additionally, NS can suggest the best routes among destinations (customers to serve) according to the average and real-time configuration of the road network (e.g., average link travel time according to time of days) (Cattaruzza et al., 2017; Chen et al., 2019, p. 20; de Moraes Ramos et al., 2020; Letnik et al., 2020; Musolino et al., 2018).

As said, an efficient and sustainable freight distribution in urban areas is a challenge both for carriers and planners. The use of technology provides various benefits. For example, using AI, it is possible to build routes with the least negative effects. The use of a BD is applicable to assess traffic congestion on a particular section of the road and combined with real time data (obtained through IoT it is possible to provide travel time forecasts). All this affects the sustainability of urban logistics because they contribute to the reduction of vehicle-kilometres travelled. The use of technology in the city helps to implement effectively the identified policies/measures and get the best possible results.

This paper analyses the popular application of technology that can push to a more virtuous behaviour of operators: optimising the use of vehicles (i.e., vehicle loads), optimising tours (i.e., reduction of kilometres travelled) both for shop restocking and e-purchase deliveries. Therefore, the focus is on: collaboration and cooperation and coordination (collaboration), multi-echelon distribution systems, crowdshipping and pick-up points (lockers). They sufficiently enable operators and planners to facilitate and improve last-mile delivery. For example, using platforms for joint coordination and cooperation, we can improve the utilisation of the vehicle, warehouses, or organize distribution optimally. Multi-echelon systems allow loads to be consolidated and improve the use of vehicles as well as to use more environment-friendly vehicles for inner-area deliveries. Crowdshipping and pick-up points could help to boost issues caused by the sprawl of e-purchases and by the absences of receivers. Akyuz and Gursoy (2020) consider that the exchange of information and the asymmetry between supply-chain partners are the key for a successful real time information-based collaboration. Important information sharing among stakeholders includes data on demand, inventory, and product traceability.

3. Systemic literature review

To perform the systemic literature review on the above identified topic, a procedure was developed. A systematic review is one of the best ways to understand the most current and novel topics, which can guide researcher discussions. The review is helpful for scientists. It can assist in understanding modern and innovative approaches, see the impacts over many years, and discover if gaps exist in the study of a given phenomenon. By synthesizing data from search engines, a network based on authors, countries, or keywords is built. More precisely, links between these attributes can be created and visualized, and clusters according to the research lines promoted in countries or along the years can be identified.

This paper shows a bibliometric analysis to determine the relationships between CL and e-ICTs (Fig. 1). In particular, among the large set of city logistics measures promoted worldwide (Russo and Comi, 2020; De Marco et al., 2018) for improving city sustainability and liveability, as previously discussed, the focus is on: collaboration, multi-echelon distribution system, crowdshipping and pick-up points (lockers).

Collaboration is gaining popularity. It allows stakeholders' aims and shared goals to be combined. Crowdshipping may be also considered to represent collaboration among professional and non-professional users. It is an innovative delivery model that could stimulate better use of currently unexploited transport capacity, thus reducing transport costs and emissions. A pick-up delivery system allows consumers to use the service at a convenient time as well as transport and logistics operators to reduce the negative impacts of delivery sprawl and failure. As discussed below and shown in Table 1, such a system has different forms and specifications, however, there is a common pattern. It consists of set of different places (pick-up points or parcel stations) stationed in the residential areas where users can take their parcels. They can be traditional or automated. The former operate through local shops or other public concerns where packages are dropped off for collection by their individual recipients. The lockers are automated and people can access packages 24 hours a day from locker boxes usually located in shopping centres, gas stations, etc. This work reviews both categories given that both use e-ICTs, and according to their functional role within the UFT, they were combined into one group. It can be looked at such a system as a multi-echelon, where the boxes work as the centre of consolidation, and the users perform the final delivery leg.

The intersection of CL and e-ICT is the object of this research. Moreover, it employs a structure in years, countries, etc. These data may show research trends and predict new perspectives. The paper reviews the different studies promoted in the fields of investigation and analyses the research aims, data collection, bibliometric analysis, visualization, and interpretation. The developed and used methodology is shown in Fig. 1, and consists of four main steps:

the first step (*initial search*) includes the choice of areas of knowledge described through the identification of some relevant keywords;

the second step (*data collection*) identifies the search keys through the concatenation of identified keywords: "multi-echelon delivery system", for example. Table 1 summarizes the queries implemented in the two used databases: Scopus (Scopus) and Web of Science (WoS). Unfortunately, when the search is carried out on two or more bibliometric databases, duplicates can be obtained. Then, the further action is to clean the dataset used for the analysis, eliminating duplicates. As a result, 992 papers from 1975 as reported in Table 1 were identified;

the third step (*bibliometric analysis*) consists of a quantitative systematic review of the literature. This is a visualization of the results (Figs. 2). A preliminary analysis refers to their cluster by year. It allows us to identify possible research trends and cutting-edge themes;

the fourth step (*thematic discussion*) highlights novel ways in the area. The analysis distinguishes existing gaps, and it allows us to identify the research trends and to suggest the further research directions.

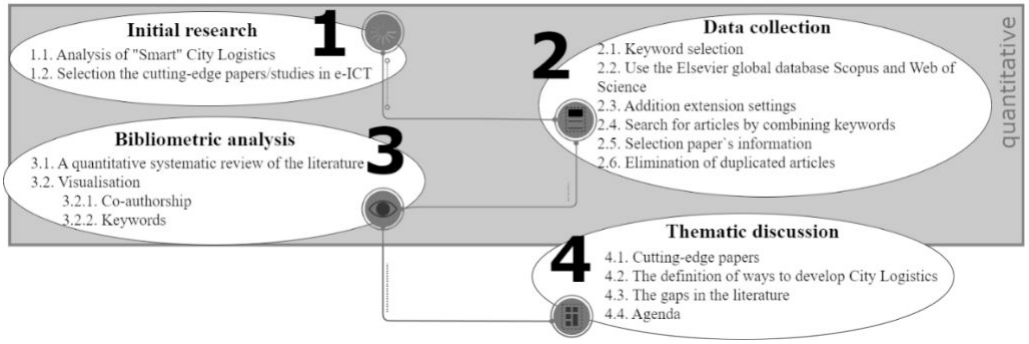

Fig. 1. Proposed methodology of literature review

The preliminary search results showed that the volume of literature on "City Logistics" in the field of "Title/Abstract/Keywords" is very large, and that most of the studies were actually irrelevant to the given topic. Consequently, the scope of the search was thoroughly obtained to ensure that the resources were relevant to the research target. Table 1 contains the result list of papers identified in databases as relevant. Subsequently, duplicates were removed and the remaining 992 records were available for further assessment.

Given that the review is performed on e-ICTs used in UFT and logistics, the first level of search has to identify the area of investigation. Then, the second level identifies the specific field of the analysis. Such a hierarchical framework allows us to ensure that the search results were relevant to the research target.

Table 1. Search keywords.

Specific field	Area	WoS	Scopus	Duplicates	Total	Total duplicates	Paper reviewed
(*collaboration* OR coordination OR cooperation)	("last mile" OR "urban logistics" OR "city logistics" OR "urban goods" OR "urban freight" OR "last mile delivery" AND ("urban logistics" OR "urban goods"))	473	445	283	637	86	**992**
crowdshipping (crowdshipping OR crowd-shipping OR crowdshipper OR crowd-shipper OR crowdshippings OR "crowd logistics" OR "crowd storage" OR "Crowd local delivery" OR "Crowd freight shipping" OR "Crowd freight forwarding" OR "personalized logistics" OR "bottom-up" OR "community-based load" OR "trip sharing service")		117	120	86	151		
pick-up points (parcel stations) ("self-picking-up delivery box" OR "pick-up point" OR "pick-up points" OR "pick up point" OR "pick up points" OR "pick-up locker" OR "pick-up lockers" OR "pick up locker" OR "pick up lockers" OR "self-service delivery point" OR "self-service delivery box" OR "parcel delivery locker" OR "postal machines" OR "parcel locker")		58	123	52	126		
multi-echelon distribution system ("multi-echelon distribution system" OR "multi-echelon" OR "two-echelon" OR "multi echelon" OR "two echelon" OR "two-echelon concept" OR "two-echelon delivery" OR "three-echelon manner" OR "three-echelon concept" OR "2-Echelon" OR "2 Echelon" OR "echelon stock" OR "multiechelon")		107	133	102	139		

3.1. Bibliometric analysis

The first step of the quantitative analysis refers to identifying the initial year of the first publication. The first article related to the topic "*collaboration*" was published in 1975 (de Neufville Richard et al., 1975). This article investigates the desirability of consolidation terminals as a means for optimizing operational costs and reducing the traffic congestion due to urban goods movements. The keyword "*crowdshipping*" was first mentioned in 2012 (Dutt, 2012). Last-mile landholding in the National e-Governance Plan in India is being attempted through a public-private partnership business model called Common Service Centre (CSC) scheme. The next papers were in 2016, a crowdshipping is gaining popularity just in these recent years. "*Multi-echelon distribution*" is younger. The number of papers is growing from year to year. Although 2023 has just begun, however, 139 papers were already published on the topic "*multi-echelon distribution system*". The "pick-up points (parcel station)" is the youngest. The total number of papers is 126 articles in Scopus and WoS. The first mention was in 2014 and a trend is not evident. However, it should be noted that such a delivery solution was a key feature of the strategy of

e-commerce and transport players by 2009, through the pick-up services network promoted by the French company La Poste, via its subsidiary GeoPost (Morganti et al., 2014). Therefore, it emerges that the investigation of lockers, multi-echelon and crowdshipping are quite new and their evolutions were pushed by the increase of e-commerce.

Undoubtedly, the issues related to ICT and smart city logistics are becoming a focus in the field of research and are expected to increase in the future. A year profile of the papers published in the Scopus and WoS databases related to CL is presented in Fig. 2.

4. Systemic literature results

The systemic literature review was performed through the VOSviewer software (Orduña-Malea and Costas, 2021). This tool can construct a visual network based on bibliographic data information for scientometric analysis. In this visual network, a node represented a specific bibliographic information type, such as author, country, keyword, etc. According to this, the programme shows us the results by keywords (Fig. 2). The software processed all specific fields. The clusters are shown by different colours.

Firstly, *collaboration* is part of cluster CL (green). Secondly, the blue cluster is named *sustainability* which the *crowdshipping* belongs to. It also has a strong connection with CL (i.e., a high number of shared keywords). Besides, *multi-echelon delivery* is part of the VPR (Vehicle Route Problem) cluster (red). The analysis revealed a direct link between the multi-echelon and CL clusters without going through the VRP one.

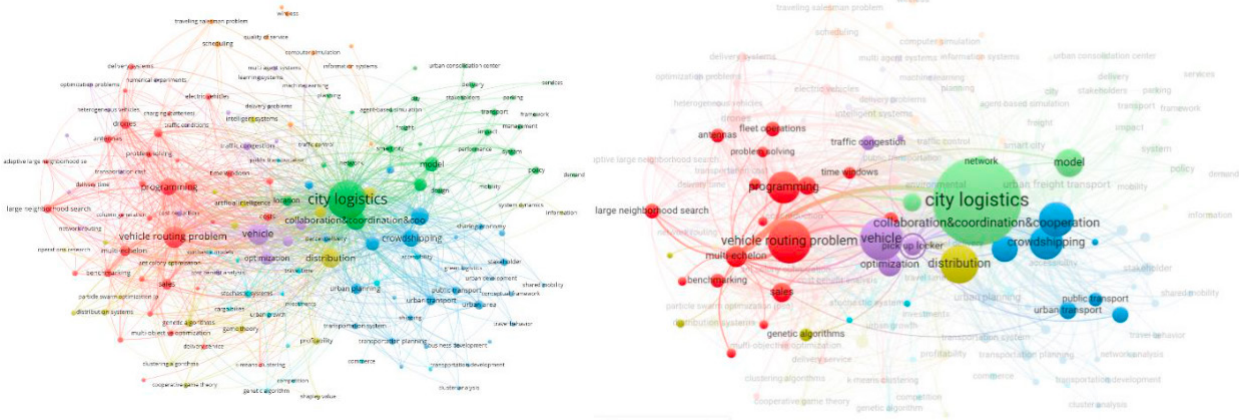

Fig. 2. (left side) visualization results (right side) with zoom in to City Logistics and VRP clusters

Collaboration between countries was evaluated, too. The top five countries that participate in described topics are China (16%), the United States of America (15%), Italy (9%), Germany (8%), and France (6%). According to this, the program emphasizes authors representing a particular country.

Table 2 presents the results in terms of set of related research fields, main authors that have contributed and the country where the research was mainly promoted. In addition to the keyword “city logistics”, the most common keywords were highlighted. Thus, the “crowdshipping” is related to *collaboration* just like the “multi-echelon” is part of the “pick-up delivery” area. An interesting observation is the connection of the studied keywords with the new delivery patterns using advanced vehicles, i.e. “drones”. A growth emerges of attention paid to sustainability and liveability of the urban areas (e.g., see SDG 11 and SUMP) as well as the increase of parcel delivering pushed the research to find new solutions investigating the four topics. The analysis also shows a strict connection among them.

Besides, the paper notes that the theme of collaboration is deeply studied in China, while the authors who have turned their attention to “crowdshipping” are concentrated in Italy. It was previously said that “pick-up delivery” is a new topic for researchers and there is a worldwide research interest. There is not a clear panel of authorship although the main studies come from Belgium, China, with a strong relationship between researchers from England and France. The “multi-echelon” attracted interest for researchers from Austria and Canada, with some works in collaboration.

Table 2. Results: connected research field and authorship.

Field of investigation	Main connected keywords	Authors	Country
Collaboration and coordination and cooperation	VRP, sustainability, urban planning, decision making, drones	Wang X., Wang Y., Wang Z.	China
Crowdshipping	Sustainability, e-commerce, model, collaboration and coordination and cooperation	Gatta V., Marcucci E., Nigro M.	Italy
Pick-up delivery	E-commerce, VRP, home delivery, sustainability, genetic algorithms, ant colony	Backers J., Cardenas I. D., Dablanc L., Morganti E. Song L., Wang J.	Belgium France, UK China
Multi-echelon	VRP, genetic algorithms, benchmarking, model, pick up delivery, drones	Hemmelmayr V. C., Nolz P. C., Crainic T. G.	Austria Canada

5. Conclusion

City Logistics plays a key role in supporting the development of the economy, sustainability and liveability of urban areas, but activities related to goods movements produces several externalities. Currently, the growing interest towards such themes, and the new trends of the sector (e.g., just-in-time, delivery sprawl and parcelling, e-commerce) has led researchers to investigate new methods and models, in particular to exploit the opportunities offered by e-ICTs. Currently, there are various approaches that propose to integrate e-ICTs in UFT. An analysis of popular applications of technologies that can optimize processes and allow operators and planners to facilitate and improve the delivery of the last mile was performed. Therefore, the focus was on: collaboration, multi-echelon distribution systems, crowdshipping, and pick-up points (parcel stations, lockers). When considering the interoperability of technologies, approaches to improve the dynamic freight management of CL stand out. The paper thus emphasized these 4 classes of technologies that directly affect UFT, as well as promote smart CL. Therefore, the paper systematically reviewed their status quo, trends and gaps. A total of 992 research papers were selected and reviewed, showing that, in recent years, these technologies have gained popularity. These innovations can help planners to support the sustainability of urban logistics.

The novelty trends in technology use were also considered. It is important to note that researchers are starting to touch on the topic of innovation. Thus, the consideration of a collaborative system leads to the need to use, for example, shared platforms with the integration of different stakeholders' systems. However, several further issues were identified, for example, data sharing, integration of different systems, merging the different needs of the involved stakeholders, and so on.

Inevitably, this work has some limitations. To avoid excessive invalid records, the search field was limited to the "keywords" field rather than the "Title/Abstract/Keywords" or "Database terms". This retrieval strategy can undoubtedly cause the loss of some literature related to the four identified topics. Besides, the selected research products were all in English while other proceedings, books, reports and manuscripts in other languages were excluded. These limitations may affect the statistical results of the study, but have little impact on the concentration of the research trends and the discussion of the topics.

The search results showed that each of the identified topics has already reached a given status of maturity within the scientific community with a significant number of papers published. Therefore, the further development of this research will be mainly addressed to investigate more in depth each of the topics in order to identify the status of their implementation, and pros and cons. Attention will be paid to shared facilities and operating resources, too. Besides, questions of data flows, interoperability and willingness for cooperation should be addressed.

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