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A Systematic Review of Innovative Technologies adopted in Logistics Management

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Abstract: Logistics and supply chain management have always been at the forefront of industrial innovations, and numerous technologies have been tested and applied with success to increase efficiency of processes, reduce costs, or improve the relationships among different actors, such as buyers, sellers, retailers and carriers. In recent times, there is a great debate in both practitioners and academic' worlds about the impacts of these new technologies on the traditional logistic operations. The perspective of extant literature on technology adoption in logistics is quite fragmented: in fact, a stream of literature studies how a technology might provide improvements in logistics processes (e.g. warehouse management, goods distribution) and/or logistics management objectives (e.g. warehouse efficiency), while other research works focus on the impact of technology adoption in terms of overall business performance. Moreover, despite the amount of articles, reports and news regarding innovations in logistics, one of the last literature review about existing technologies applied in logistics has been published almost ten years ago and it is limited only to ICT technologies. Therefore, we reckon the need for an updated view on the literature in this field. Through a systematic literature review, we try to give an answer to the following research questions: i) how the interest in this topic changed in the last ten years from the point of view of scientific literature; ii) what are the main approaches and methodologies used in addressing this issue; iii) what are the most applied innovative technologies in the logistics field.

Keywords: innovative technologies, logistic management, systematic literature review

1. Motivation and Research Questions

Logistics management is related to the planning and implementation of an efficient flow of materials and information from point-to-point and through a business (Cooper, Lambert and Pagh, 1997). In this sense, logistics management is the link between the supply and demand of goods, and includes a wide range of activities spanning between different companies and geographical contexts. Often, logistics management and supply chain activities take a significant portion of costs in a typical business; for this reason, cost reduction is one of the major driver for outsourcing logistics activities to specialized companies (Hsiao *et al.*, 2010). One of the main cost component in logistics is transportation costs (Swenseth and Godfrey, 2002). Moreover, inventory is often a hidden cost that should be constantly monitored, making inventory management a critical aspect of supply chains (Gunasekaran and Kobu, 2007). The mission of logistics management encompasses other aspects besides cost reduction. Customers' requirements are changing quickly in recent years, and companies need to achieve operational flexibility to account for volatile demands, high product variety, short product life cycles, and short lead time (Soni and Kodali, 2010). In order to avoid responding to customer requirements at the expense of cost reduction, logistics managers are called to aim at efficiency through assets maximization and processes optimization. Technology adoption can help logistics managers navigating through the complexity of the above-mentioned logistics objectives. Information-based technologies and capabilities are positively related with supply chain and logistics flexibility (Shang and Marlow, 2005), and are the antecedents of information sharing enabling reduced lead times (Cachon and Fisher, 2000). Therefore, logistics and supply chain management have always been at the forefront of industrial innovations, and numerous technologies have been tested and applied in these fields. However, logistics managers should be aware of all the advantages and disadvantages of a technology in order to exploit its potential. With this regard, the perspective of extant literature on technology adoption in logistics is quite fragmented. In fact, on the one hand, a stream of literature studies how a technology might provide improvements in the logistics activities previously mentioned (Yang *et al.*, 2018) and/or the aspects that characterize the logistics management mission (e.g. efficiency), (Liu and Geng, 2016). On the other hand, a second stream of literature focuses on the impact of technology adoption in terms of overall business performance (Leitão, Colombo and Karnouskos, 2016), considering logistics as an individual part of a business. Moreover, despite the amount of articles, reports and news regarding innovations in logistics, one of the last literature review about existing technologies applied in logistics has been published almost ten years ago (Perego, Perotti and Mangiaracina, 2011) and it is limited

only to ICT technologies. Therefore, we reckon that high is the need for an updated view on the literature in this field. Through a systematic literature review, we try to give an answer to the following research questions:

- How the interest in this topic changed in the last ten years from the point of view of scientific literature?
- What are the main approaches and methodologies used in addressing this issue?
- What are the most applied innovative technologies in the logistics field?

The objective of the study is to provide evidence about the interest of scholars on the technologies supporting the logistics management.
The paper is structured as follows. In section 2, the methodological steps taken to perform the systematic literature review are stated. Then, in section 3 a first outlook on the preliminary results are presented, focusing on descriptive statistics. In section 4 and 5, we delve deeper into the type of technologies revealed in the literature, together with their field of application. Finally, discussions and conclusions are drawn in section 6.

2. Methodology

The Systematic Literature Review (SLR) is selected as the research method for this study because of the nature of its goal, which aim at understanding the more cited topic in the scientific literature.
A review earns the adjective "systematic" if it is based on clearly formulated questions, identifies relevant studies, appraises their quality, and summarizes the evidence by use of explicit methodology. Moreover, a SLR provides a replicable research protocol (Tranfield, Denyer and Smart, 2003) and the detailed documentation of the performed steps within the SLR enables in-depth evaluation of the conducted study.
This study followed the guidelines provided in the most prominent articles (Touboulic and Walker, 2015) to devise a robust and replicable study. In particular, a three-step protocol was developed to identify a valid procedure for performing an automated research, so the SLR can be replicated by other researchers (Lagorio, Pinto and Golini, 2016).

Step 1: Inclusion/exclusion criteria

First, a preliminary list of the keywords (i.e., logistic/s, technology/ies, innovations) and inclusion criteria were identified, and the concept of new technologies in logistic was defined by its various possible synonyms in the keywords, making our research as comprehensive as possible. For space constraints we do not report the complete list of keywords that is available upon request.
Moreover, the research focused on papers published in refereed journals in the field of logistics, operations, management and economics for the period (2010-2018). The starting year was selected because the last literature review about this topic goes back to 2011 (Perego, Perotti and Mangiaracina, 2011). Therefore, the review was limited to peer-reviewed publications to gain consistency between themes and sources (Touboulic and Walker, 2015) and to ensure the quality of the selected papers.
The search was launched based on a first set of criteria similar to that reported in Table 1. SCOPUS database was selected for the analysis. Following this, a double-blind control test was performed (Tranfield, Denyer and Smart, 2003) on papers to verify and refine the selection criteria. More specifically, each author carried out a manual selection of the articles to verify their coherency with the inclusion and exclusion criteria. Every paper that met with disagreement regarding inclusion/exclusion criteria was read and discussed until agreement was reached. This led to the definition of the final selection criteria reported in Table 1. The query was then launched again, which resulted in the extraction of an initial corpus of 130 papers.

Table 1. SLR Inclusion Criteria

Inclusion Criteria	Description
Keywords	Logistic/s AND Technology/ies, Innovations
Language	English
Document types	Articles
Source types	Peer-reviewed Journals
Time Interval	Jan. 2010-Mar. 2018

Step 2: Selection based on title and abstract

Each researcher reviewed the titles and abstracts of selected papers. Following a discussion among the authors, papers out of the research scope were removed from the corpus. In particular, 63 papers that did not focus strictly on technologies in logistics were excluded from the corpus.

Step 3: Selection based on full text and snowballing

The last step of the protocol involved the refining of the list of selected papers. After reading the full versions of candidate papers, 22 papers were not in the scope of our research were excluded from the corpus (Figure 1). The complete list of papers is available from the authors upon request.

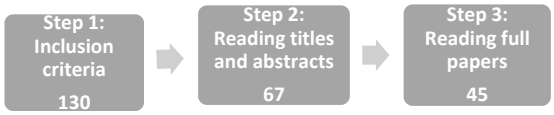

Figure 1. Systematic literature review results according to the selection protocol

3. Results

3.1. Papers per year

Figure 2 presents the distribution by year of the papers in the corpus. Despite some fluctuations in the considered time interval, it is possible to state that the number of published paper remains quite constant in the examined period. It is also possible to appreciate the steep increase of contributions regarding technologies in logistic in the last year, thus confirming the current, growing relevance of the subject. Further, in the first three months of 2018, two

papers have been already published, thus confirming the current trend.

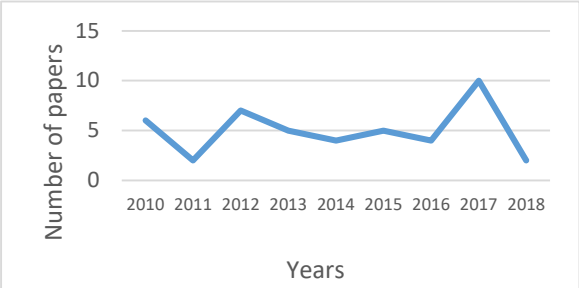

Figure 2. Papers distribution by year of publication

3.3. Perspective on technology

The adoption of technology in a specific field of application or industrial sector can be investigated through different perspectives. Some scholars can use the literature to build hypothesis and theoretical models on the impacts that a consolidated deployment of technology has on a specific aspect of a business. For instance, Tsai and Tang, (2012) assume from the literature that the degree of RFID adoption positively affects operational performance, and then test this hypothesis through a large-scale survey. This type of papers is therefore referred to as *ex-post* papers. On the other hand, technology uptake can be explored via a modelling framework or in-depth case study, focusing on the implementation steps, barriers and advantages to a future adoption of the technology. This set of works can be referred to as *ex-ante* papers.

There is an almost perfect split between these two perspectives, as 22 papers adopted an *ex-ante* view whereas 23 used the opposite perspective. As mentioned above, *ex-post* studies rely heavily on large-scale surveys, which accounts for 17 papers out of 22. The remaining six papers use content analysis, network analysis and multiple case study (Figure 3).

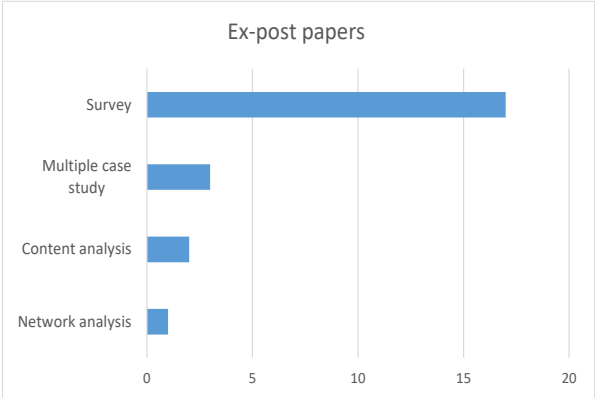

Figure 3. Methodologies in ex-post papers

On the contrary, *ex-ante* papers are more scattered across various research methodologies. In this regard, the most exploited methodologies are single study, by eight papers, and optimization methods by five papers (Figure 4).

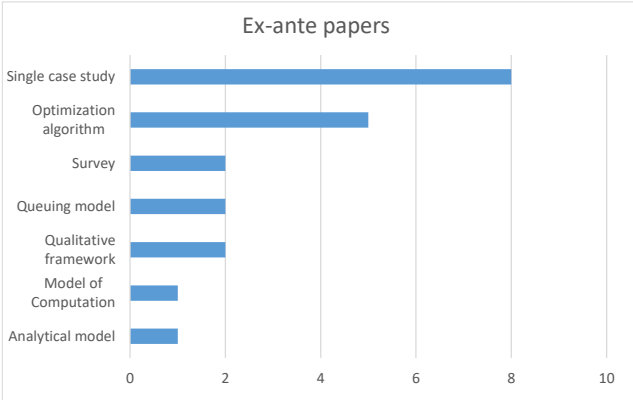

Figure 4. Methodologies in ex-ante papers

4. Description of technologies

In this research, Supply Chain (SC) and Logistics technologies can be defined as tools and technologies that may be implemented in order to integrated SC management within and across the organizational boundaries (Liu, Prajogo and Oke, 2016). SCs are often integrated with Enterprise Resource Planning (ERP), that is a computing system designed for automating the flow of materials, information, and financial resources among all the functions in a common database (Su and Yang, 2010).

Different technologies have been adopted for managing and dealing with the SC and logistics processes. Some of them have reached a significant level of maturity and are currently largely used. On the contrary, there are new technologies that are becoming crucial, and their application is gradually spreading in the logistics arena. In this context, Logistics Information Technology (LIT) can be identified as applications used for planning, implementing and controlling all the procedures for the transportation and storage of goods, and services from the point of origin to point of consumption (Hazen and Byrd, 2012). In the last few years, cloud computing has been proved its viability in the logistics industry. Indeed, it allows accessing software applications and data storage with zero initial fixed initial investment (Subramanian, Abdulrahman and Zhou, 2015). Two very important technologies in the field of the IT for logistics are the Data Electronic Interchange (EDI) and the Radio-Frequency Identification (RFID). The EDI technology is used to exchange information across organization and it can be defined as a business-to-business transfer of repetitive processes involving direct routings of information from one computer to another without human interference, and according to predefined formats and rules (Hazen and Byrd, 2012). The RFID is based on tag read by electromagnetic devices and passed to a radio transmitter where an RF carrier transmits it to a distant receiver able to register and managing the information (de Azambuja *et al.*, 2010). Its main aspects are that no line-of-sight is required, the simultaneous high speed reading of multiple tags, and the identification of all the units in a stock-keeping unit (Gu *et al.*, 2017). The viability in terms of user friendliness can significantly influence the adoption of RFID among companies (Ramanathan, Ramanathan and Ko, 2014). More recently, Internet of Things (IoT) is gaining

momentum. Its main characteristic is the concept of bringing together people, process, data and things. IoT facilitates the way people, data and things work and interact. The aim is to make networked connections more relevant and valuable (Ferretti and Schiavone, 2016). In this context, the importance of big data for modelling and analysing urban transport and distribution systems through large dataset created by different source of information such as GPS, cell phone, and transactional data of company operations, becomes crucial (Mehmood *et al.*, 2017).

From a more product-oriented point of view, it is noticeable Additive Manufacturing (AM), defined as the process of joining materials to make objects from 3D model data, usually layer upon layer. This technology is expected to impact on SC structure (such as the location of the manufacturing facility) and logistics (transportation and warehousing) (Durach, Kurpjuweit and Wagner, 2017). By posing the attention in warehousing processes, more importance is associated with the use of Autonomous Vehicle based Storage and Retrieval Systems (AVS/RS) that consist of autonomous vehicles, lift and a rail guide-pack within the rack area (Roy *et al.*, 2015).

5. Technology fields of application

Among the new technology trends, the ones related to fleet management, SC platforms, and vehicle-optimization technologies are considered as crucial in logistics systems (Cassetta *et al.*, 2017). Moreover, not only radical, but also incremental technological innovations can benefit logistics (Nascimento and Petraglia, 2016). The competencies in SC can be also enhanced by adopting ERP in the organization (Su and Yang, 2010).

In can be stated that an investment in ICT has positive impact on the performance of the SC in terms of quality and timeless of data along the chain. Benefits are related to company's competitiveness, image, and value added (Nguyen and Tongzon, 2012). The survey carried out by Belvedere and Grando (2017) shows that this effect is particularly high in the todays digital transformation revolution. ICT enables information to be readily available along the SC members for speeding up logistics activities such as order exchange or inventory management (Hafeez *et al.*, 2010). Another survey by Evangelista *et al.* (2012) demonstrates that there is a positive correlation between IT and SC financial performance both at strategic and operational level. The recent dramatic grow of e-business has been also called companies to pay more attention to the critical relationship between their ICT systems and SC in order to gain consequent better integration, competitiveness and value added (Nguyen, 2013).

However, a project initiative need to be carefully assessed, since typical complex relationship among the element of a logistics system, related to the intra and inter-interdependences can jeopardize the positive effect of IT investment that may not automatically translate into real improvements for the adopting firm (Hazen and Byrd, 2012). In addition, the success of IT can differ between inbound and outbound logistics, in the sense that the goals drive the adoption for inbound and the challenges impact of the adoption for outbound (Hazen *et al.*, 2014).

RFID technology have been largely used and still studied, and many innovative projects in R&D have been carried out (de Azambuja *et al.*, 2010). In logistics processes, RFID applications are widely investigated adopted (Zhong *et al.*, 2015). Thanks to the unique tracking capability, RFID is able to reduce inventory shrinkage, and improve efficiency and responsiveness in both short and long term. Recent applications demonstrate its feasibility in humanitarian SCs wherein after a disaster a quick responsed to the needs of the victim is the prime concern (Biswal, Jenamani and Kumar, 2018). Another application of the RFID is its integration with the demand planning to facilitate the adjustment of the lot size to the real demand that is monitored by the RFID system (Gu *et al.*, 2017). More specifically, RFID can be successfully applied in the food industry for dealing with the inventory quality issue, enhancing the timeframe requested for actions and, in turn, improving the customer satisfaction level (Lao *et al.*, 2012). In healthcare environments, RFID is used for tracking and tracing of medical supplies, high value products, mobile assets, patients, and hospital staff. In particular, the real time visibility allows for improved delivery of services (Moatari-Kazerouni and Bendavid, 2017). Furthermore, in the jewelry sector RFID, besides the positive influence on the logistics activities, there are opportunities also for marketing innovation related to new services that can be added to customers (Neubert, Dominguez and Ageron, 2011). Finally, the use of RFID represents also from the wholesaler point of view a value adding functionality, and this could motivate suppliers to update their systems (Hinkka, Främling and Tätilä, 2013) such as ERP and Warehouse Management Systems (WMS), that are often not designed for RFID data systems (Teo *et al.*, 2011). Thus, RFID is a lever for implementing service innovation (Tsai and Tang, 2012) and it can be considered as a catalyst for more rapid process improvements (Zailani, Fernando and Zakaria, 2010).

More recently, Internet of Things (IoT) is demonstrating its ability to improve the operational efficiency in SC processes. Indeed, IoT technologies are becoming an IT standard across seaports, such as the case of Hamburg port (Ferretti and Schiavone, 2016). In this context, another effective technology is the x-ray scanner that bring a lot of benefit such as security, labour efficiency, theft and pilferage reduction, expedited handling and cargo inspection cost savings (Min *et al.*, 2015). Moreover, cloud computing, is more and more considered as a viable way to obtain world-class inexpensive capabilities to meet the increasing demands for high-quality and cost effective services. In particular, logistics service providers can be able to improve their services, achieve a better planning, and reliable day by day operations, with less investment. (Subramanian, Abdulrahman and Zhou, 2015). However, a successful ICT adoption need to be based on a harmonization of the technology that can be promoted by both public authorities (that can make compulsory the adoption of a specific standard) and by port operators (that might have the power to force other players to use certain standards) (Coronado Mondragon, Coronado Mondragon and Coronado, 2017). As well as big data that coach on the interconnectivity can substantially support customers,

public authorities and transportation company in a mutual reciprocity (Mehmood *et al.*, 2017). If big data are combined with Smart City issues meant as environments wherein ICT and sensors systems are embedded into physical objects, they can support improvement initiatives in SC. For example, real time traffic information can provide short-terms predictions of the rates of traffic flows and travel speed for improving vehicle routing and transportation planning (Tachizawa, Alvarez-Gil and Montes-Sancho, 2015).

Thus, as indicated by (Göpfert and Wellbrock, 2013) the development of innovative SC concepts will become more and more a competitive factor. More broadly, the advanced implementation of product and process flow management are able to improve the operational performance of an organization (Huo, Han and Prajogo, 2014). Innovations are viable in reverse logistics too for improving its activities such as collection, organization and processes (Sathish and Jayaprakash, 2017).

In the field of warehousing systems, AVS/RSs are used to achieve greater operational efficiency and drive competitive advantage, especially in high-density storage areas (Roy *et al.*, 2015).

From an organizational perspective, integration and synergies among different companies in the logistics activities can improve operational capabilities (Subramanian *et al.*, 2016). The operational processes can be also made more efficient by innovations in packaging. For instance, a reduced packaged weight have direct positive effects on transport costs (Vernuccio, Cozzolino and Michelini, 2010). Also, effective Returnable Transport Packaging reduces or even eliminates waste at the final customer, minimizes risks to the environment, and reduce warehousing costs (Yusuf *et al.*, 2017).

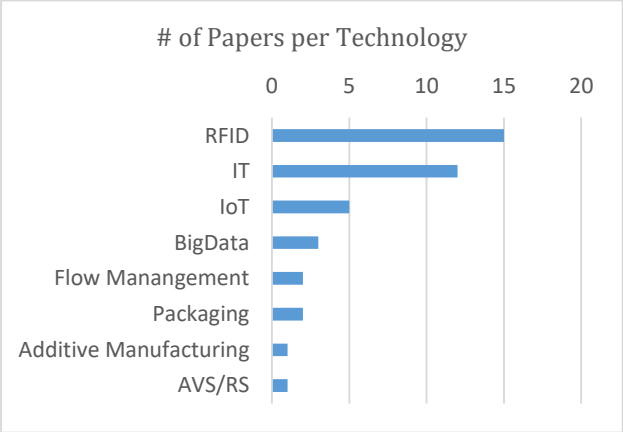

Figure 5. Technologies investigated in the papers

Figure 5 groups the papers in each technology taken into account. In particular, RFID is at this point a mature technology that has broadly proven its effectiveness in logistics management as demonstrated by the highest number of related papers. IoT and Big data, even though have been recently adopted, are showing a particular interest by academics.

6. Conclusions

One of the goal of this research is to give an overview of the topic of innovative technologies in logistics. As a matter of fact, only relevant academics efforts have been included in the study. The need to summarize the literature associated with different technologies applied in logistic comes up from the great fragmentation of the current literature on this topic since few studies have been carried out in the last ten years. Moreover, in the last two years (2015-2017), this topic raised more and more interests in the scientific literature, as emerged from the analysis of papers per years (Figure 2). Furthermore, it can be observed that going beyond the differences among ex-ante and ex-post approach, all the papers are mostly explorative-oriented, and only a few report real performances after a new technology implementation.

Regarding the implemented technologies, the most cited are the RFID technology and the IoT. The first one is the most used and consolidated technology. The second one is a more recent and expanding technology, especially coupled with the use of Big Data. From the SLR, IoT seems to be a very promising technology that will be used and implemented in the field analyzed in this study.

However, this research suffers from limitations. In particular, the research is limited to the peer-reviewed journals, and it does not take into account conference papers that could provide interesting information about new frontiers of the research in this field. Moreover, future research will be focused on the maturity of the technologies exploited by logistics management, in order to identify the technology trajectory.

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