Chapter 1

Introductory Chapter: Industry 4.0 and Its Impact on Logistics - A Retrospective Review

Tamás Bányai

Additional information is available at the end of the chapter

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1. Introduction

The increased complexity of customers' demands led to the globalisation of economy. This caused increased transportation and material handling intensity which is perceivable in all four functional parts of logistics: purchasing, production, distribution and inverse processes. The globalisation, the demographical changes, the urbanisation and the sustainability influence the expected performance of manufacturing and service processes. The Industry 4.0 and its technologies offer new solutions to fulfil customers' demands, while economical, ecological, social and engineering impacts are taken into consideration.

Within the frame of this short introductory chapter, the main research directions of Industry 4.0 are shown focusing on logistic applications. The following questions are answered with a short literature review: Who is doing what? Who first did it or published it? What are research gaps?

2. Conceptual framework and review methodology

Within the frame of this retrospective literature review, the systematic literature review (SLR) methodology of Cronin et al. [1] was used including the following aspects: define research questions, select sources from Web of Knowledge, reduce the number of articles, identify the main research directions, define a methodology to analyse the chosen articles, discuss the main scientific results and identify the scientific gaps and bottlenecks.

The relevant terms were defined. The first search using the topic 'Industry 4.0' keyword resulted to 1066 articles, but a wide number of the articles have no relation with logistics;

therefore, the following keywords were used to search in the Web of Knowledge database: the topic 'Industry 4.0' and topic 'logistics'. Initially, 59 articles were identified. The search was conducted in July 2019; therefore, new articles may have been published since then.

3. Descriptive analysis

The articles can be classified depending on the research area. **Figure 1** shows the classification of these 59 articles considering 10 subject areas. This classification shows the majority of engineering and management sciences, while the operational research and computer sciences define the importance of computational methods related to the design of logistics and supply chain solutions in Industry 4.0 environment. The classification shows that sustainability, energy efficiency and environmental impact of logistic solutions of cyber-physical systems get more and more importance.

As **Figure 2** demonstrates, Industry 4.0 and its effect on logistics and supply chain solutions have been researched in the past 5 years. The first article in this field was published in 2015 in the field of cloud computing [2], and it was focusing on the importance of cloud-assisted solutions of the emerging Industry 4.0 theory focusing on logistics and sales. The number of published papers has been increased; it shows the importance of this research field, especially in automotive industry.

As **Figure 3** demonstrates, most of the articles were published in journals with sustainability and manufacturing topics. The distribution of journals shows that the research of logistics and supply chain solutions in cyber-physical systems and Industry 4.0 environment is a multidisciplinary topic.

In the following step, the 59 articles were reduced after reading them. Articles whose topic cannot address the effect of Industry 4.0 on logistics were excluded, and some

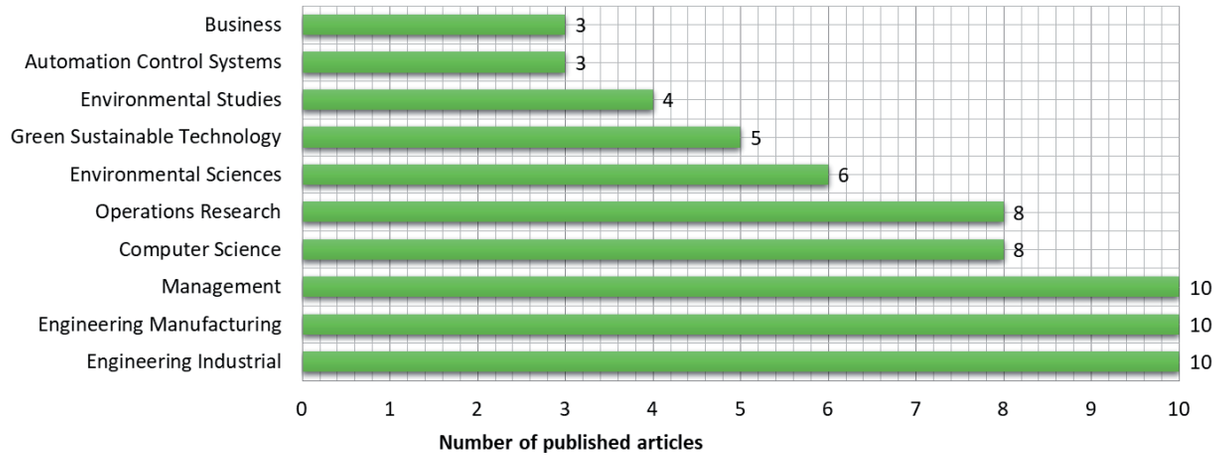

Figure 1. Classification of articles considering subject areas based on search in Web of Knowledge database using the topics 'Industry 4.0' and 'logistics'.

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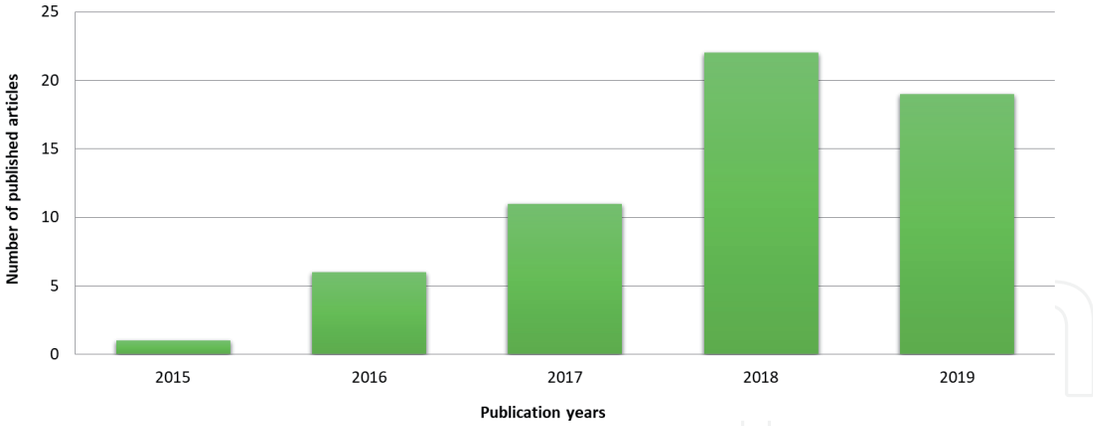

Figure 2. Classification of articles by year of publication based on search in the Web of Knowledge.

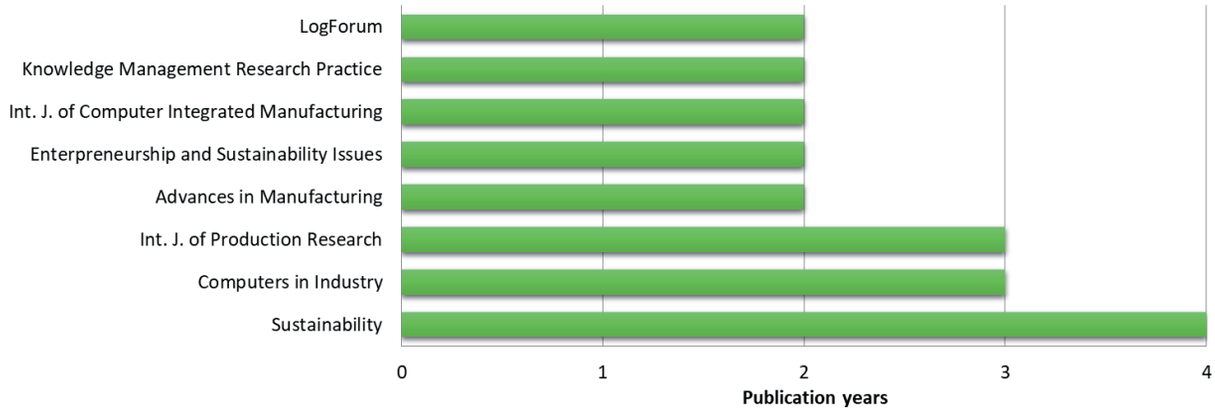

Figure 3. Distribution of Industry 4.0 and logistic-related articles in journals, based on search in the Web of Knowledge.

articles were added from different research platforms. After this reduction and addition, we got 18 articles. The next section describes the content analysis of these articles and defines a framework of available sources related to the impact of Industry 4.0 in the field of logistics.

4. Content analysis

The fourth industrial revolution is also known as 'Industry 4.0', 'Smart Manufacturing' or 'Integrated Industry', but all of these names cover the integration potential of value making chains from design, through production, to distributions and inverse processes. This potential is especially focused in just-in-time and just-in-sequence processes of automotive industry [3]. Industry 4.0 has a great impact on logistics of production [4] and service processes [5]. The lean paradigm (or lean manufacturing) is linked to the development and operation of cyber-physical systems, because it is widely regarded as an efficient improvement tool in Industry 4.0 environment [6]. Another aspect of the importance of lean manufacturing in

Industry 4.0 is that both cyber-physical systems and lean manufacturing can be characterized with decentralized control [7]. The globalisation of the economy led to the increased importance of sustainability and the minimization of environmental impact; therefore Industry 4.0 should include not only purchasing, manufacturing and distribution processes but also the inverse operations of the closed-loop economy [8]. The realisation of cyber-physical systems requires the integration of networking, organisational development, structural frame conditions and sustainability which in fact has a great impact on the logistic solutions in manufacturing and services [9]. The first-mile and last-mile operations of a supply chain solution represent complex optimization problems, because routing, assignment and scheduling problems should be taken into consideration. The Industry 4.0 technologies make it possible to make real-time decisions in the first-mile and last-mile processes in order to design a cost-efficient sustainable collection or distribution process. These design problems are NP-hard; therefore heuristic and metaheuristic solutions are required to solve them [10, 11]. Another revolutionary design method is the online optimization. Online optimization can support to solve real-time challenges [12] in complex supply chain processes or in-plant material handling systems.

Logistics and value chain will be influenced by the new solutions of Industry 4.0 technologies. Researches based on Porter's value chain model show that an increased economic sustainability can be achieved with the application of IoT tools, Big Data technologies and cyber-physical systems [13].

Bressanelli et al. [14] identified eight functionalities of Industry 4.0 technologies (improving product design, attracting target customers, monitoring and tracking product activity, providing technical support, providing preventive and predictive maintenance, optimising the product usage, upgrading the product, enhancing renovation and end-of-life activities) and analysed their impact on closed-loop value drivers, like resource efficiency, lifespan and closing the loop. These eight functionalities of Industry 4.0 technologies are important not only for manufacturing but also for logistic operations and supply chain processes. Case studies validate the impact of Industry 4.0 technologies on supply chain solutions. These case studies are based on manufacturing processes of Logistics Knapp AG, Nova Chemicals, BMW, Stratasys and Bosch [15].

The logistic operations include not only the in-plant supply processes but also the material handling operations of warehousing. The increased complexity of manufacturing processes led to increased complexity of component portfolios which led to complex warehousing processes. In the case of real-time data and contextual information, these complex warehouse processes can be improved through Industry 4.0 technologies [16]. The success of applied Industry 4.0 technologies depends on the characteristics of manufacturing environment [17]. The manufacturing environment can be described with the level of automation, level of product repetitiveness or type of products.

Researches show that the most important Industry 4.0 technologies applied in the field of logistics are focusing on the support of product identification and increase of traceability of products and resources [18]. **Table 1** shows the research framework represented by the reviewed articles from objective, methodology and case studies point of view.

	Cloud computing	Supply chain	Lean manufacturing	Closed-loop economy	Organisation	Heuristics	Online optimization	Real-time decision	Internet of Things	Optimization	Service	Manufacturing	Case studies
Yue et al. (2015) Cloud-assisted industrial cyber-physical systems [2]	X												
Hofmann and Rusch (2017) Industry 4.0 and the current status as well … [3]		X										X	
Sanders et al. (2016) Industry 4.0 implies lean manufacturing … [6]			X									X	
Jabbour et al. (2018) Industry 4.0 and the circular economy [8]		X		X									
Prause and Atari (2017) On sustainable production networks for … [9]		X			X							X	
Banyai (2018) Real-time decision making in first mile and … [10]		X				X		X		X	X		

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	Cloud computing	Supply chain	Lean manufacturing	Closed-loop economy	Organisation	Heuristics	Online optimization	Real-time decision	Internet of Things	Optimization	Service	Manufacturing	Case studies
Nagy et al. (2018) The role and impact of Industry 4.0 and the … [13]		X			X						X	X	
Buer et al. (2018) The link between Industry 4.0 and lean … [7]			X									X	
Bressanelli et al. (2018) Exploring how usage-focused business … [14]				X	X								
Banyai et al. (2018) Smart scheduling: an integrated first mile … [11]		X				X		X		X	X		
Szozda (2017) Industry 4.0 and its impact on the functioning … [15]		X			X						X		X
Lee et al. (2018) Design and application of Internet of … [16]						X			X		X	X	

	Cloud computing	Supply chain	Lean manufacturing	Closed-loop economy	Organisation	Heuristics	Online optimization	Real-time decision	Internet of Things	Optimization	Service	Manufacturing	Case studies
Strandhagen et al. (2017) The fit of Industry 4.0 applications … [17]									X			X	X
Trappey et al. (2017) IoT patent roadmap for smart logistic … [18]									X		X		
Dunke et al. (2018) Time traps in supply chains … [12]						X	X			X			
Tamás et al. (2017) New challenges for quality assurance … [5]		X	X								X		
Nagy et al. (2018) Impact of Industry 4.0 on production logistics [4]		X										X	

Table 1. Research framework and main topics of logistic-related research in Industry 4.0.

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5. Consequences of literature review

The above described short literature review shows that the application of Industry 4.0 technologies offers innovative solutions for both manufacturing and logistic processes. Cloud and fog computing supports the solution of Big Data problems. Heuristic, metaheuristic and online optimization make it possible to solve NP-hard problems of complex logistic processes and supply chains. The adoption of bar codes and RFID technologies focuses on identification and traceability of products, resources and processes. In logistic processes, the importance of real-time decisions gets more and more importance, because real-time decisions can increase the efficiency of resources through an improved flexibility. Why is it necessary to put so much effort into the application of Industry 4.0 technologies? However, the application of Industry 4.0 technologies in logistics leads to new manufacturing technologies and logistic solutions, but the design and operation of these new processes and systems required sophisticated models and methods to build complex, efficient, sustainable solutions.

Author details

Tamás Bányai

Address all correspondence to: alttamas@uni-miskolc.hu

University of Miskolc, Hungary

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