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INDUSTRY 4.0, DIGITALIZATION, AND BIG DATA: PERSPECTIVE OF LOGISTICS AND SUPPLY CHAIN MANAGEMENT

Hazar DÖRDÜNCÜ[1], Zemzem Selin ORUÇ[2]

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ABSTRACT

Logistics and supply chain management has been affected by the developments in systems that are being digitized day by day. Along with digitalization, big data obtained from various sources allows logistics and supply chain components to exchange information throughout the process. The information exchange can provide data collection, and the collected data can be analyzed to enhance the logistics and supply chain processes. The purpose of this paper is to cover digital developments, their applications, and their impacts on logistics and supply chain management. Based on this objective, first, the literature review on digitalization, internet of things, big data, data mining is presented. Second, the theoretical explanation on how these concepts are utilized and also impact upon the traditional supply chain processes is provided.

ENDÜSTRİ 4.0, DİJİTALLEŞME VE BÜYÜK VERİ: LOJİSTİK VE TEDARİK ZİNCİRİ YÖNETİMİ PERSPEKTİFİ

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ÖZ

Lojistik ve tedarik zinciri yönetimi, günden güne dijitalleşen sistemlerdeki gelişmelerden etkilenmiştir. Dijitalleşme ile birlikte çeşitli kaynaklardan elde edilen büyük veri, lojistik ve tedarik zinciri bileşenlerinin süreç boyunca bilgi alışverişinde bulunmasına olanak sağlamaktadır. Gerçekleştirilen bilgi alışverişi, veri toplama sağlayabilir ve toplanan veriler lojistik ve tedarik zinciri süreçlerini geliştirmek için analiz edilebilir. Bu makalenin amacı, dijital gelişmeleri, uygulamalarını ve bunların lojistik ve tedarik zinciri yönetimi üzerindeki etkilerini ele almaktır. Bu amaçla öncelikle dijitalleşme, nesnelerin interneti, büyük veri, veri madenciliği ile ilgili literatür taraması sunulmaktadır. İkinci olarak, bu kavramların nasıl kullanıldığına ve ayrıca geleneksel tedarik zinciri süreçleri üzerindeki etkilerine ilişkin teorik açıklama sunulmaktadır.

[1] Dr.Öğr. Üyesi, Nişantaşı Üniversitesi, Uluslararası Ticaret ve İşletmecilik Bölümü, hazar.dorduncu@nisantasi.edu.tr, ORCID: 0000-0002-9481-2063.
[2] Arş. Gör., Nişantaşı Üniversitesi, İİBF, Yeni Medya Bölümü, selin.oruc@nisantasi.edu.tr, ORCID: 0000-0002-8582-998X.
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INTRODUCTION

Digitalization has evolved many industries including but not limited to health, transportation, education. While it affects the vital aspects in daily life and business life, logistics and supply chain management (SCM) are also included in this evolution. Digitalization of organizations and businesses is a significant subject since it would provide integration and sustain consistent growth. The cyber-physical systems that are formed naturally by the developments in digitalization, supplies various data from different sources. That makes the organizations and businesses to be eligible of acquiring valuable data to their benefit. The advantageous nature of digitalization and the big data that are provided by these sources are attractive subjects for many recently. These advantages of big data acquirement by digitalization are being used in logistics and SCM to alleviate their challenging processes. This paper considers the elements of digital development along with data usage and how it enables advantageous applications in logistics and SCM.

In the logistics and SCM literature, the mostly referred study in the international platform on the digital supply chain is presented by Wang, Gunasekaran, Ngai & Papadopoulos, 2016 focuses on and classifies the impact of analytics of work on the management of the supply chain (Wang et al., 2016). Another important study is presented by Wang et al., 2017, which looks into the development of big data, the necessity of forming an action mechanism within the logistics process such as shipping/transportation, storage, distribution, etc. within which great benefits can be obtained by the involved individuals when installing logistics center by using the big data technology (Wang, Feng, Chang, & Wu, 2017). In the year 2018, Tiwari, Wee & Daryanto studied analytics and the application of big data in the SCM between the years 2010 and 2016 in order to provide a sectoral insight (Tiwari, et al., 2018). Within a similar scope, Zhong, Newman, Huang, & Lan, 2016 evaluated in their work the usage of big data in the supply chain from the perspective of services and manufacturing sector in separate studies focused on the current inclinations and future perspectives of big data usage in the operations and SCM (Zhong et al., 2016; Lamba & Singh, 2017; Schoenherr & Speier-Pero, 2015).

The studies in Turkey in the relevant field, however, are newly dated. Industry 4.0 Revolution and the innovations it has brought in the logistics sector is studied by Akben and Avşar in 2017. After assessing the supply chain and digital supply chain processes, fundamental characteristics of cloud computing, the distribution, and service models of cloud computing; they evaluated main concerns on the security and compatibility aspects in the process of transition into the cloud computing system in the supply chain (Akben & Avşar, 2017). Özdemir and Özgüner in their study presented a case study on the reflections of Industry 4.0 on the logistics sector (Özdemir & Özgüner, 2018); whereas Saatçioğlu, Kök, & Özispa, (2018) targeted the general structure of the digital supply chain, expediting the supply chain activities of businesses and making them more productive (Saatçioğlu, et al., 2018). The other studies in the relevant literature include Yıldız's work on the general structure of digital supply chain, its relation with Industry 4.0, a transition from traditional to digital supply chain, characteristics, factors, and benefits of the digital supply chain (Yıldız, 2018); İyigün's work on the use of big data in the processes of logistics and supply chain (İyigün, 2019); and Terzi, Gür, & Eren's (2020) study on the use of methods of Analytical Hierarchy Process (AHP) and Analytical Network Process (ANS) as well as their prioritization in terms of the potential opportunities presented in the process of the sustainable supply chain via the use of Internet of Things (IoT) for Industry 4.0 transition (Terzi et al, 2020).

The paper is organized as follows. The first part of the paper includes a brief introduction about how digitalization and big data are examined in the literature of logistics and SCM. Then, Industry 4.0 and digitalization are given in the first section of the paper. In the second part, the concept of big data is explained along with the big data logistics. The third section consists of other applications of Industry 4.0 such as RFID and IoT usage in logistics and SCM, and the artificial intelligence (AI) applications. Lastly, the paper is concluded, and future works are given.

1. INDUSTRY 4.0 AND DIGITALIZATION

Logistics and SCM are the pivotal elements in the 21st century, as they are critical for meeting the increasing demand of consumers. Shipping processes and warehouses are in a highly demanding nature of the logistics and supply chain ecosystem. Understanding the requirements of this ecosystem requires a well-designed strategy to sustain the cost-efficiency while satisfying the customer requirements. Managing the whole process in an efficient way is a complex problem. Therefore, strategic planning in a digitally developing century needs semi-automated or automated systems. Thus, the industry of logistics and SCM has started to evolve to Industry 4.0. The evolution of Industry 4.0 is illustrated in Fig. 1.

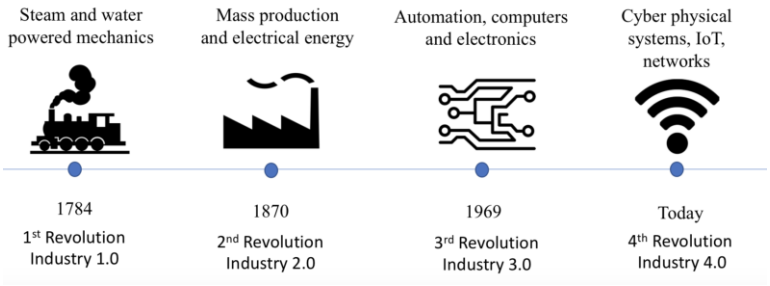

Fig. 1: Evolution of Industry 4.0. (Kalaria, 2018)

Industry 4.0 includes various resources exchanging big amounts of data being generated and collected like the IoT, cyber-physical systems, and cloud-based systems. These systems provide automation for businesses while enhancing efficiency by the opportunistic usage of the data. By the usage of these data generated and collected, in-dept business analyses can be acquired to be used in many dimensions. The combination of physical operations with smart digital technology brings the term of industrial IoT (IIoT). Integration of IIoT to logistics and SCM brings smart approaches to conduct these processes.

IIoT enables logistics and SCM, increased accessibility for efficiency with the significantly big amounts of data, called big data, being collected and integrated. The integration of big data to the SCM and logistics to automate the process with Industry 4.0 elements. Exploiting this data opportunistically is a process of data-driven optimization. Reaching the real-time data, forecasting, and designing the process are transiting to key operations with data-driven techniques. The data-driven applications in cyber systems in the physical context revolutionized the logistics and SCM to "Logistics 4.0" and "smart SCM" (Galindo, 2016). As the demand for logistics and SCM is high, the data-driven opportunities that can be used in logistics and SCM should be investigated further (Dubey et al., 2019).

2. BIG DATA CONCEPT

The usage of generated and collected data for increasing the efficiency of logistics and SCM is eligible within the concept of big data. Big data is the vast amounts of data are collected from many resources such as mobile phones, Global positioning system (GPS) signals, social media streams, and sensors. The variety of data that can be collected from various devices is huge. These diverse data are eligible to be analyzed and used in almost every area of life. SCM and logistics are the areas that are available for the opportunistic usage of these vast data being generated. Big data analytics (BDA) is applied for efficient supply chain design. The supply chain needs to be conducted by selecting optimal planning and satisfying the needs of consumers. Wang et. al. (2016) included the BDA for their model of distribution channel localizations. Their study shows that behavioral data have lessened the complexity of the supply chain process while covering consumer needs. From the warehouse to the end-customer, the process provided a significant advantage with behavioral big data extracted from the data-driven models.

Data-driven models have become an alleviate for ease of works and optimizing the processes with the increased amount of data produced every day. The big volumes of data that are being produced in everyday life have different kinds of variations. The examinations revealed the big data characteristics in "three Vs"; Volume, Velocity, and Variety (Laney, 2001). The transformation with the information technologies brings efficiency for the SCM and logistics by the features it brings.

The nature of big data collections creates integration and links the customer with supply chain and logistics businesses. This plays a key role in SCM and logistics because reaching the customer with more insights would improve the quality of SCM and logistics processes. Besides, location-based information can be accessible with the availability of big data to be processed for the benefit of SCM and logistics.

2.1. Big Data Logistics

Big data logistics is used for the optimization of processing, organizing the functions and workflow in factories hence considered as beneficial for the supply chain processes of logistics and transportation companies. In the 21st Annual Meeting on Third-Party Logistics, 98% of third-party logisticians stated that decision-making based on improved data is "necessary for the future success of supply chain activities and processes". In the same

meeting, 81% of shippers and 86% of third-party logisticians asserted that the effective use of big data would become the main competence of supply chain organizations (Lebied, 2017).

The semi-automated recognition of the patterns by humans from big data is data mining. Data mining is used for finding out the patterns in a big dataset. The usage of data mining and BDA provides meaningful patterns from the big data available.

The data being collected from digital sources are being used for monitoring and managements. In the highway, seaway, and sea transportation, the use of telematics (telecommunication and information technologies combined) and advanced GPS monitoring solutions able the fleet managers to track the location of their vehicles, report on fuel consumption, observe carrier behaviors and manage vehicle maintenance processes. This continuum starts with the collection of data by telematic equipment installed in the vehicles in the field, and their delivery to a platform or software to be used by the fleet managers. The collected data includes information on the vehicle operation, malfunction, and maintenance services, as well as information on the personnel. Because this software provides an aerial viewpoint to the fleet managers, they are able to control in real-time the profitability and efficiency of their fleet. The fleet management resolutions are formed by the aggregation of various telematics services for monitoring and management as specified below.

Fleet Monitoring: The digitalized systems should be monitored in real-time for alleviating the undesired non-digitalized system features. Fleet monitoring is used for this purpose with the real-time interaction with information systems (Vivaldini, Pires, and Souza, 2012). For fleet monitoring, GPS receivers/satellites, GPRS (mobile phone) networks, and cloud computing technologies are used. GPS receivers acquire data on its current location via GPS satellite, transfers this data to cloud system through GPRS (mobile phone) network, and then the processed data is submitted upon software to the fleet manager (Filord.io, 2019).

Efficiency Management: Detailed reports on the fleet consumption data can be submitted to fleet managers by means of telematic resolutions. Fleet managers can control fleet efficiency due to the real-time reporting on data on fuel consumption, vehicle operation scorings, operations out of working hours, and infringements of duty areas.

Maintenance and Malfunctioning Management: Vehicle maintenance and resource management are vital solutions when planning the lifecycle of the vehicles in the fleet. The potential malfunctioning or costs are minimized by means of real-time services including the usage information of the vehicles, kilometers, maintenance service periods.

Security Management: This resolution helps fleet managers to avoid potential accidents and reach driver safety standards is mainly used for the prevention of adverse conditions such as accident notifications, overspeed detection, rough driving activities, and vehicle theft.

Insurance Management: Insurance companies benefit from telematic resolutions in order to observe driver behavior and use the data as effective reference points when pricing their insurance policies.

Big data requires a high-quality source of information in order to effectively function. In logistics, sources of information of good quality also wide in scope can be reached through (Lebied, 2017):

- Traditional institutional data received from operational systems,
- Data on traffic and weather conditions transmitted from sensors, monitors, and estimation systems,
- Data on vehicle identification, driving systems, and location,
- Estimations on financial management,
- Data on advertisement feedback,
- Data on internet browsing and social media.

It is clearly observed that numerous companies started to interiorize big data after realizing its benefits and its impact on their institutions. Furthermore, logistics has become very complex due to shipping processes, traffic, increasing fuel prices, driver shortage, weather conditions, and governmental regulations. Therefore, the use of big data in transportation can simplify all related transportation services. In this context, this study lists 5 areas in which big data can be used within the context of logistics and supply chain:

a. **Use of Big Data in Goods Transport:** One of the greatest benefits of using big data is the assistance it lends to companies in tracking the shipments of goods and materials. Companies can track down the process of the shipping of consumables from start to finish. The instant tracking of goods and equipment, as well as the planning of the time of delivery can be organized by using RFID and IOT technologies. For instance, in some cases it might be possible that the shipping officer might have some difficulties in finding the destination point or might

hit a traffic jam. In these cases, it is highly likely that the shipping officer would be unable to deliver the product on time and keep the recipient waiting. Therefore, it is very difficult for the recipient to estimate and trace the length of the delivery. Big data technology comes in useful in this tracking process and overcoming the problem caused by this potential delay. By means of big data, the shipping process of goods and equipment can be monitored simultaneously in real-time from start to finish. The recipient can track down his/her purchase on the smartphone and hence check the delivery status with the help of real-time insights provided by the supplier. In a similar vein, the delivery process can also be traced by the company delivering the product for the purposes of locating the real-time location of the vehicle, how far it has moved away from or how far is left to reach the delivery location. At the end, the transportation process becomes transparent both for the customers and companies (Joshi, 5 Use Causes of Big Data in Logistics, 2019). Furthermore, many big companies use RFID tags, such as Wal-Mart, in their good shipments for the overall shipment processes (Rozados & Tjahjono**,** 2014).

b. **Use of Big Data for Route Optimization:** Big data is also used for route optimization in logistics and SCM. One of the greatest challenges for logistics companies is to ensure that their operations are highly optimized to maximize profits and keep costs at the minimum size. Route planning for the last kilometer delivery is particularly difficult as it also takes into account of the drop-off times (Valmonte, 2021). Since the logistics process involves the transportation of products that might cause a strait, big data comes in useful in terms of identifying the causes. It is also possible to designate the shortest route for the delivery vehicle. Supplier can also get hold of data on weather reports and traffic updates by big data technology through sensors installed on the vehicles. Suppliers therefore can save on fuel which is located at the top of the list of expenditure items and can help the delivery of supplies faster than normal time. The big data analysis experts in a global analytics and consultation company who conducted research on route optimization confirmed that BDA reduce the costs of expenditures by helping the companies to proactively react to the incoming and outgoing incidents. Besides, they observed that this process helps logistics service providers to enhance the supply chain processes and build solid structures.

c. **Use of Big Data for the Delivery of Perishable Goods:** Big data can be used for bringing in the products of the highest quality. For instance, perishable supplies such as milk products should be delivered on time. The delayed delivery of milk products by the delivery vehicle might spoil the milk products. In that respect, companies can provide their customers with high-quality and healthy products by means of big data technology and sensors. In fact, the safety of perishable goods such as food can be maintained by the delivery officials and the companies based on the data information transmitted from the heat sensors installed in the delivery vehicle for the purposes of monitoring the quality of products stored in the vehicle (Joshi, 5 Use Causes of Big Data in Logistics, 2019).

d. **Use of Big Data for Warehouse Management:** In today's conditions, managing smart warehouses with big data aided applications is a significant topic. Planning the stock, transfer, transport is the some of the aspects in logistics and SCM to be concerned about. The concerns on warehouse management are being eased by several applications. To give an instance from the literature, the optimization of these concerned features, Zunici Delalic, Hodzic, Besirevic & Hindija, 2018, proposed a concept for smart warehouse management with the usage of AI techniques for optimization with the collection of big data. Furthermore, another concern that is unacceptable for the companies is an online problem for them being out of stock after an order is placed. In these cases, the company must bear an additional cost for re-stocking the product or inform the buyer of the mistake they made in stock control and explain why they cannot supply the purchased product. In such a case, it is highly likely that the customer would choose a rival company to buy a product. At this point, big data technology can come to e-commerce companies' rescue. Recently, companies such as Amazon, Alibaba, and DHL have internalized "smart warehouse" for the effective stock control of the stored supplies in the warehouse. In contrast to traditional warehouses, smart warehouses increase speed, performance, and efficiency. Smart warehouses can utilize big data technology via real-time insights provided by this technology integrated with IoT and electronic shelf tags, big data allows you to track your

warehouse inventory in real-time and organize and manage stock replenishment much more effectively (Solum Marketing, 2021). By this way, big data technology can provide an efficient warehouse management. For another instance in smart warehouses, Geest, Tekinerdogan, & Catal, 2021, explained the dynamic slotting, the technique that is called chaotic slotting is being used in companies recently, such as Amazon (Geest et al., 2021). A chaotic warehouse or chaotic slotting refers to a type of location management that is irregular, random, variable or unrestricted. Site selection process in chaotic slotting often follow a very strict order based on stock rotation and thus on A-B-C product classification (Interlake Mecalux, 2019).

e. **Use of Big Data for the Improvement of Customer Services:** Customer services can be improved by using big data technology; helps customer feedback and protect the institution's reputation. Therefore, it is highly important to receive customer feedback regularly to help the improvement of the company. The data of consumer behavior can be collected in real-time, can be used for the analysis of consumer behavior. These real-time analytics solutions ensure that the service quality and profitability of your business remains at desired levels without any official effort (Mehra, 2013). Thus, well-defined consumer behavior ensures the competitive advantage to businesses in a highly competitive market by recognizing the social behavior (Shmueli, Singh, Lepri, & Pentland, 2014).

3. OTHER INDUSTRY 4.0 APPLICATIONS

3.1. RFID and IoT

Radio-frequency identification (RFID) enables communication by transferring the data with a reader and an RFID tag. RFID technology is like conventional barcodes, but RFID tags include digital data that are readable via radio waves (Evdokimov et al., 2010). In that way, the desired data can be identified. RFIDs can be used to connect the Internet to provide connectivity in tracking, monitoring, identifying, or such applications that can happen in real-time and providing security by preventing counterfeit (Sun, 2012). This connection to the Internet is referred to as IoT. The data provided with RFID and its applications in IoT have a broad range of areas to be used. These applications can enhance the capabilities of many devices and processes. SCM and logistics processes are also able to be enhanced with the RFID and IoT applications. Since real-time tracking and identifying the tagged objects are crucial aspects for SCM and logistics, RFID applications in IoT are promising solutions for increased efficiency (Golicic et al., 2002). The way how RFID works are represented in Fig. 2.

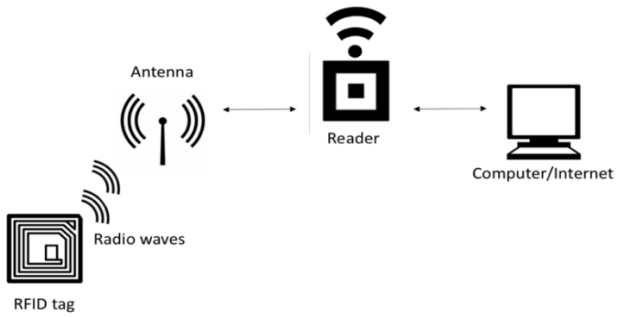

Fig. 2: Working Principle of RFID (Thomas, Thomas, & Bashari Rad, 2017)

A network created with the RFID systems provides smooth data transmission with simple tags or sensor-enabled technologies. This transmission allows one to get insights into the desired information within the network. Along with the IoT systems, the tagged or sensor-enabled products can be tracked and monitored in real-time. This feature can alleviate the difficulty of designing a non-problematic supply chain and logistics process. The data transfer within these systems can also help gain and analyze the insight information. Therefore, the supply chains and the logistics can have improved forecasting. Forecasting prohibits possible future obstacles and prevents the unforeseen costs of these obstacles. This prevention is advantageous for the SCM and logistics businesses to stand out in the highly competitive environment. The optimization of supply chain and logistics and IoT enables these processes to be agile, responsive to real-time changes, adaptable, and linked with high integration. The information gathered from this optimization also benefits the competitors while it supports the

linkage with the customer and the product statuses. From the warehouse to the marketplace, the dynamic structure can be conserved.

In 2020, it was reported that the growing companies spend about $500 billion on industrial IoT applications (Artificial Intelligence, 2021). The development of the industry brings more complexity for the SCM and logistics while the competitiveness is increasing in the parallel direction. Especially the growing businesses want to keep up with the competition and handle the complexity that is growing. The IoT applications meet the requirements by lessening the unforeseen obstacles and avoiding the problems while increasing efficiency.

3.2. Artificial Intelligence

The data availability makes it possible to utilize the data as it would be in benefit of the process. AI is like data mining which is used for discovering the patterns from large datasets, also used for recognizing patterns from big data. Moreover, it is automated because it can be done by a machine and predict an outcome. Over the years, AI in the logistics sector has been subject to a serious transition and development. The impact of new technologies on supply chain and logistics is rapidly increasing whilst numerous businesses are situated in digital transformation. Businesses are fully aware of the fact that it is highly crucial for them to benefit from AI and big data in their daily operations in order to stay in the game field and gain a competitive advantage. Although AI and the related computer of things might seem as newly acknowledged concepts, they have been used for a long time in the field of logistics.

To make the logistics and SCM smart and automated, the big data collected from the many connected devices can be processed by AI. AI is defined as a technology that "applies advanced analysis and logic-based techniques, including machine learning, to interpret events, support and automate decisions and take actions" (Artificial Intelligence, 2021). The continuously increasing demand on the labor requirement necessitates a human-like intelligence that can do the reasoning, recognition, learning, decision-making, or solving complex problems to be supported. Many studies have referred to digitization and the transition in the SCM and logistics. This transition and changes are being changed by the new technologies (Capgemini, 2016). The desired SCM and logistics processes require good timing, placing, and consistent quality to get the customer content while being cost-effective (Mangan & Lalwani, 2016). Therefore, the optimization should be done for efficiency. The demand on SCM and logistics increases along with the increased production, makes these processes more complex to be designed. Therefore, an intelligent way to help these complex problems is needed (Butner, 2010). The responsive and adaptive nature of AI can solve complex problems since it has a higher capacity than a human mind to recognize complex patterns. The integration of AI decreases the forecasting errors and allows monitoring and track the whole process smoothly. The predictive nature of AI provides smart SCM and logistics.

The big data generated with IoT devices and many various recourses, robust SCMs, and logistics designs can be conducted and thus, can be improved with the usage of big data in AI applications. Through these applications, the risks can be minimized (Calatayud, 2017), and significant data analyses can be actualized. The literature of AI and SCM considered risk mitigation (Bogataj & Hudoklin, 2017) a self-thinking supply chain and suggested to contribute both in practitioner and academic approaches (Calatayud et al., 2019) automation and forecasting (Klumpp, 2017), a system that can choose the path in a ware-house for picking the orders (Allen & Helferich, 1990). However, the literature only has a few examinations that fully understand designing enhanced SCM and logistics processes with AI. The complete integration of AI can reduce the necessity of optimization in agile processes, increase the insights of customer needs and provide content to customers, making the process more cost-effective and more efficient with fewer errors.

In contrast, as it can be seen in the section 2.1, although AI and other smart technologies are widely operationalized in almost all ranks in the logistics sector, they had not been used comprehensively and in full capacity until recently. Since it became clear that the elements of AI can be used for fleet management resolutions and smart transportation, these elements also started to be integrated into storage operations, scaling of inventory management, order systems, advanced consultation, and robotic systems. In this context, the introduction, analysis of all data and identification of all patterns in the supply chain are considered vitally important for the conversion of big data information into action. In this line of reasoning, Vijay Raja, the Industry, and Marketing Director of Cloudera states that it is extremely important to master in the big data lifecycle to improve process performance. Therefore, it is important to receive and process data through various sources including external data clusters such as weather conditions, geopolitical implications, local activity calendars, or social observations (Freeman, 2020).

CONCLUSIONS AND FUTURE WORK

Digital developments made significant transitions in the processes of logistics and SCM. Along with Industry 4.0, smart applications and data-driven models automated many of the operations and increased the efficiency for the benefit of businesses and customers.

Technologies such as the IoT and big data logistics can be used to optimize the delivery routes and to make emergency plans in the cases of unavoidable interruptions in these routes. In this way, companies can guarantee an efficient delivery regardless of the setting they carry on a business. It is necessary for companies to have access to correct data via big data sources, AI, and digital twin technologies in order to obtain the best results. This involves external data that may be related to weather conditions, the impact of a pandemic, or a sudden seasonal increase in demand. As the amount of information absorbed by the algorithm is determined so the insights would all that become applicable. The thing that makes artificial so important is, when used correctly, the necessity of companies to subsist a trade-off experience. They, therefore, can be fast-moving, active, and accurate.

Our study suggests that supply chain and logistic businesses can use big data and its analytics along with data mining to gain more insights about much information needed to smooth the SCM and logistics processes. With the help of big data, all logistics activities in the supply chains will be able to provide instant optimization according to all conditions and will enable them to take a better position against any situation.

In this context with the use of digital technologies in business operations together with benefits such as efficiency, cost, saving, and transparency in business process has been clearly observed.

Therefore, the evolution will be continued as the digital developments continue and the data being generated. Thus, possible future applications can be examined. This study aimed to evaluate the digitalization and big data, and their applications of their usage in logistics and SCM. Scenarios and case studies can be investigated for further extensive study.

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Author Contributions

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