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A New Approach to the Logistics 4.0 Measuring Model in SMEs

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Abstract: *An important source of competitive advantage for logistic functions is to include the processes brought using the Industry 4.0 approach in their business models. The main problem is how to measure the logistics 4.0 levels of enterprises. Therefore, this study aims to develop a model for measuring the degree of logistics 4.0 (DoL_4.0) in SMEs. This measurement model is based on the usage scores of logistics 4.0 technologies used in businesses, usage scores in logistic activities, and the number of technologies used. Second, the relationship between DoL_4.0 and firm performance was examined. Our data were collected using the convenience sampling method in Gaziantep, Turkey. Because this research was an exploratory study, data were collected from 57 companies. In order to test the study topics, correlation analyses were conducted. The findings revealed robust correlations among the variables under investigation. The paper concludes with a discussion of the management and theoretical implications of the study's findings.*

1. INTRODUCTION

Industry 4.0 is a sophisticated infrastructure that leverages the following technologies: robotics, automation, big data, artificial intelligence (AI), the Internet of Things (IoT), additive manufacturing (3D printing), the cloud, and cybersecurity. The notion initially surfaced in a governmental publication in Germany in November 2011, followed by a resurgence of the term "Industry 4.0" in April 2013 during an industrial exhibition held in Hannover, Germany. The notion of Industry 4.0 has been the subject of extensive discussion and implementation in both academic research and corporate operations. The permeation of all business operations has been subject to the digital transformation mandated by Industry 4.0 since the term "Industry 4.0" was first used in 2011. One of the most vital industries, logistics, has incorporated innovations of the new industrial revolution into its procedures ever since the advent of Industry 4.0. Strandhagen et al. (2017) proposed that logistics 4.0 was an approach driven by technology and provided the following illustrations:

- Logistics 4.0 utilizes big data analytics in real time to determine the most efficient routes for transporting materials and products by analyzing vehicles, product volume, and facility locations.
- Logistics 4.0 reduces the amount of stock needed for mass manufacturing by measuring on-site and on-demand.
- In warehouses, autonomous robots and vehicles, along with tracking and decision-making systems, maintain strict control over inventory.
- Logistics 4.0 enables a reduction in the bullwhip effect by real-time exchange of information among different actors.
- Smart products and cloud-supported networks keep the information flow intact.

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Determining the degree of logistics 4.0 (DoL 4.0) in small and medium-sized enterprises (SMEs) is the objective of this research. Exploratory in nature, this study seeks to establish a framework for quantifying DoL 4.0. This measuring model is made up of the ratings of how well logistics 4.0 technologies are used in businesses, how well these technologies are used in logistics operations, and the total number of technologies that are used. Later, an analysis was conducted to investigate the correlation between DoL 4.0 and firm performance.

The subsequent inquiries into research were addressed in order to accomplish the primary aim of this manuscript:

RQ1: What are the technological elements of Logistics 4.0?

RQ2: How to assess the DoL_4.0?

RQ3: How to assess DoL_4.0 in SMEs in Turkey?

RQ4: What are the effects of DoL_4.0 on firm performance?

2. LITERATURE REVIEW

According to Vargas et al. (2023), Industry 4.0 is distinguished by the intelligent, horizontal, and vertical integration of people, machines, objects, information, and communication technologies (Veile et al., 2020). The digital transformation of production systems constitutes Industry 4.0. This revolutionizes production into a human-free system capable of accumulating and analyzing data, making decisions, and communicating with other systems autonomously (Nantee & Sureeyatanapas, 2021; Sureeyatanapas et al., 2023; Thoben et al., 2017). Technologies such as cyber-physical systems, the Internet of Things, cloud computing, cognitive computing, 3D printers, and the Internet of Services are integral components in the advancement of Industry 4.0. The logistics business has seen a profound transformation as a result of the applications of Industry 4.0. Logistics 4.0 is the result of the Industry 4.0 Revolution, which has prompted logistics organizations to implement novel business models and procedures. Consequently, greater autonomy will prevail in every facet of logistics. “Logistics 4.0 and smart supply chain management in industry 4.0” (i-SCOOP, 2017) presented Figure 1, which depicts the road map developed by UNITY Consulting and Innovation. Winkelhaus and Grosse (2020) proposed a range of technologies, including Big Data, IoT, Cyber Physical Space (CPS), Cloud Computing, mobile systems, and social media-based systems, as potential means to digitalize logistics 4.0. In order to facilitate digital transformation (Vial, 2021), logistics 4.0 employs intelligent trucks, pallets, containers, and transport systems.

Büyüközkan and Göçer (2018) believe that logistics 4.0 is predicated on the implementation of cutting-edge technologies including Big Data, IoT, and AR. Logistics 4.0 is an intelligent, adaptable, flexible, and productive system (Hrouga & Sbihi, 2023).

The Internet of Things (IoT) is a network of physical objects or “things” that can be accessed through the Internet. According to Kubáč (2016), IoT is characterized by the presence of integrated technology that enables these objects to communicate with either internal or external environments. IoT, according to Tran-Dang et al. (2022), has arisen as a revolutionary innovation that transforms the way in which objects are connected and communicate. Enhancing the operational effectiveness of logistics activities, attaining valuable and real-time data, and optimizing the logistics process with regard to fleet and traffic management, inventory control, asset utilization, safety, and security are all possible with the Internet of Things.

Treiblmaier (2018) provided the following definition of blockchain technology: "A decentralized, distributed, and digital ledger in which transactions are recorded and appended in a sequential fashion, with the intention of establishing immutable and tamper-resistant records." Liao and Wang (2018) highlighted the advantages of blockchain technology in the logistics industry, including the simplification of product tracking and the interchange of digital documents. Blockchain technology may have a significant impact on certain logistics and supply chain operations, according to Raja Santhi and Muthuswamy (2022). These operations may include the creation of a product traceability mechanism, the detection of counterfeit or gray market goods, the enhancement of product visibility, and the elimination of paperwork and administrative burdens that persist throughout the product life cycle. Implementation of blockchain technology can reduce or eliminate obstacles associated with logistical characteristics, such as delivery delays, documentation loss, product origin obscurity, and errors. Simultaneously, the adoption of blockchain technology offers several advantages, including enhanced sustainability, decreased occurrences of errors and delays, optimized inventory management and transportation, expedited problem detection, heightened confidence (both among consumers and business partners), and improved security (Tijan et al., 2019).

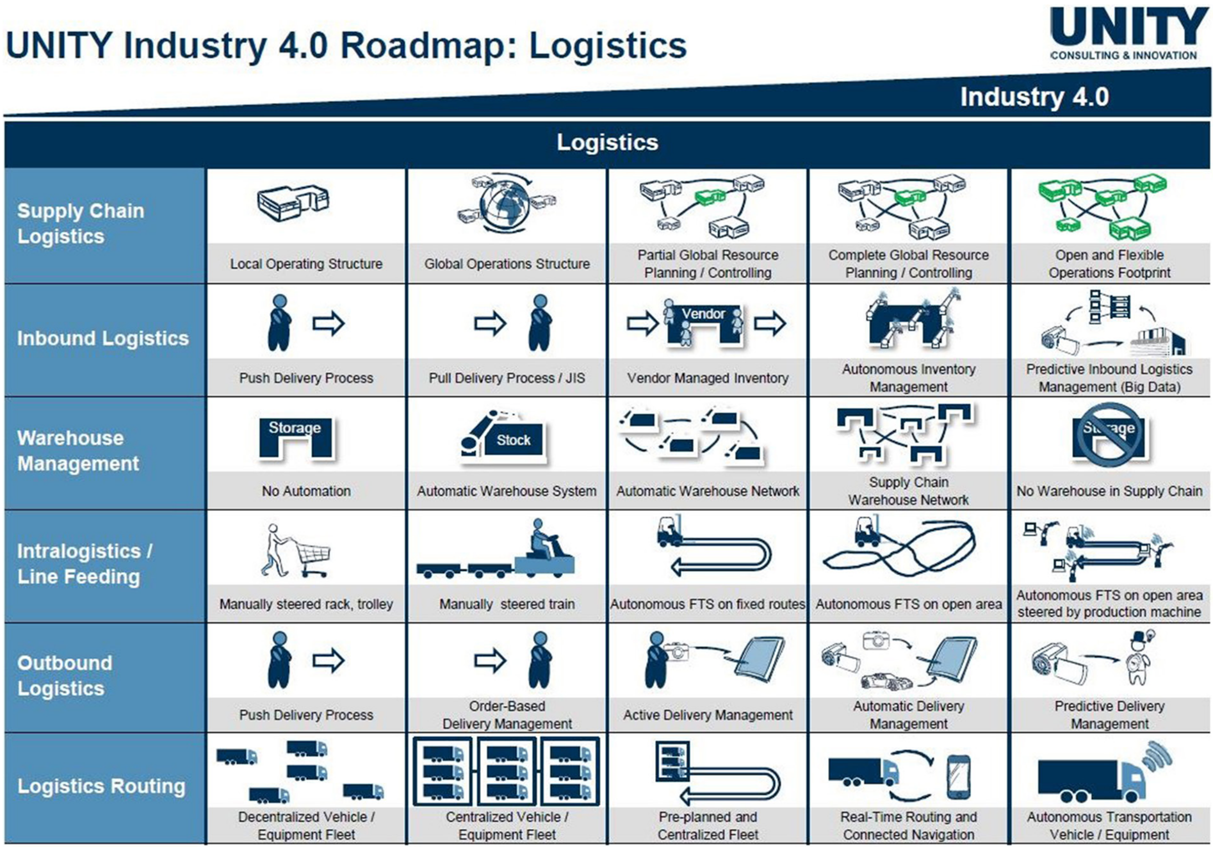

Figure 1. UNITY Industry 4.0 Roadmap: Logistics

Source: i-SCOOP, 2017

Big data is a term coined by Liu et al. (2019) to describe "expanding, heterogeneous data sets in structured, unstructured, and semi-structured formats" (Oussous et al., 2018, p. 433). Additionally, the term "big data" refers to "a collection of data sets that is both substantial and intricate, rendering conventional data processing applications and database management tools inadequate for their processing" (Furht & Villanustre, 2016, p. 3). The following attributes define big data; they are referred to as 3Vs+1 (Kubáč, 2016):

- Volume – size of data,
- Variety - various data formats,
- Velocity - the speed of generation of data,
- Veracity - The quality of the data, and
- The other V is Value – benefits from data.

Utilizing big data analytics, one can enhance the efficiency of logistics operations, oversee supply chain procedures, mitigate supply chain vulnerabilities, optimize worldwide transportation, and manage client information.

Cyber security systems comprise a collection of technologies, rules, tools, guidelines, security safeguards, security concepts, risk management approaches, training, and best practices. These components are designed to secure the user assets, company, and cyber environment. Cybersecurity is defined by the International Telecommunications Union (ITU) as "a collection of risk management approaches, tools, policies, security concepts, safeguards, guidelines, actions, training, best practices, assurance, and technologies that can be employed to protect the assets of an organization and its users within the cyber environment" (Von Solms & Van Niekerk, 2013). Establishing a secure cyberspace by eliminating or lowering cyber hazards (or cyber threats) in a digital network for the logistics business is the objective of cyber security in logistics management (Cheung & Bell, 2021).

Augmented reality (AR) is a technology within Industry 4.0 that is presently garnering considerable attention from the industrial sector. AR is defined as any endeavor in which the primary objective is to enhance the physical environment by incorporating virtual data that deepens human perception and capabilities (Cirulis & Ginters, 2013, p. 17). Tablets or glasses can be utilized in warehouse operations to assist with AR in logistics, including the verification and tracking of goods received, the storage placement of incoming items, and the routing of storage location information. As a result, it is extensively utilized and offers significant benefits in the domains of shipping and order selection (Lagorio et al., 2022). An additional application domain encompassing augmented reality applications is the education of logistic operators.

Robotization: The utilization of robots to perform (a portion of the) labor that was formerly performed by employees in business processes is the definition of roboticization (Berkers et al., 2023). This has been an ongoing practice for decades. An autonomous robot is classified as an intelligent machine that executes designated duties with a significant level of independence (Shamout et al., 2022). Autonomous robotic vehicles provide the logistics industry with solutions and benefits including a reduction in labor and expense costs, enhanced productivity and dependability, improved job quality and safety, and diminished hazards of human error and damage (Tubis & Poturaj, 2021).

Artificial intelligence (AI) is a technological advancement that enables machines to replicate, learn, and augment human intelligence (Ding et al., 2021). AI enables machines to acquire knowledge through experience, adapt to new inputs, and execute activities resembling those of humans (Ding et al., 2021). The most effective application of AI to increase the operational efficiency of the logistics sector is the intelligent warehouse. Utilizing AI in warehouses has significantly enhanced logistical operations, including storage density, picking accuracy, and handling speed (Zhang, 2019). The application of AI in transportation and product delivery presents many prospects and obstacles. Furthermore, it is imperative to conduct a thorough analysis of data security and privacy issues while implementing AI in the logistics industry to safeguard the confidentiality and integrity of sensitive data (Richey et al., 2023).

3. METHODOLOGY

The research focuses on SMEs based in Gaziantep, Turkey. We communicated with firm executives and explained the purpose and procedures of our study. Then, managers who accepted the research made a face-to-face questionnaire. A total of data[3] was collected from 57 managers. We used the convenience sampling method. We develop a measurement methodology to assess the degree of logistics 4.0 (DoL_4.0) in SMEs. In the methodology, we first determine about 22 related technologies of Industry 4.0 (IoT, Blockchain, 3D printer, Bigdata, Drone, GPS, Robotization, AR, AI, etc.). Second, respondents graded the degree of use of technology of Industry 4.0 in all business activities on a 10-point scale with anchors ranging from Not Use (=0) to Highly Use (=10). Likewise, finally, we wanted these technologies to be given points for only logistic activities.

We developed DoL_4.0 using six indicators (Ind):

- Ind_1: The ratio of a firm's Use Score of Industry 4.0 Technology to Total Score in all business activity *[It refers to the ratio of the score obtained by any company from the use of Industry 4.0 technologies to the total score (total number of measured Industry 4.0 technologies*highest measurement score)].*
- Ind_2: The ratio of firm's use number of vehicles of Industry 4.0 to total vehicles in all business activity *[It refers to the ratio of the number of Industry 4.0 technologies used by any company to the total number of technologies measured]*
- Ind_3: The ratio of firm's Use Score of Technology of Industry 4.0 to Total Score in only logistic activities, *[In only logistics activity, it refers to the ratio of the score obtained by any company from the use of Industry 4.0 technologies to the total score (total number of measured Industry 4.0 technologies*highest measurement score)]*,
- Ind_4: The ratio of firm's use number of vehicle of Industry 4.0 to total vehicles in logistic departments, *[In only logistics activity, it refers to the ratio of the number of Industry 4.0 technologies used by any company to the total number of technologies measured]*
- Ind_5: The mean of firm's use in all business activity, *[It refers to the mean that their use score of Industry 4.0 technologies to the number of technologies]*,
- Ind_6: The mean of firm's Use in only logistic activities, *[In only logistics activity, it refers to the mean that their use score of Industry 4.0 technologies to the number of technologies].*

Finally, DoL_4.0

$$DoL\_4.0 = Ind_1 + Ind_2 + Ind_3 + Ind_4 + Ind_5 + Ind_6$$ was calculated.

Firm performance was measured using three components: financial (four items), market (three items), and export (five items) performance. We have adapted the measures of firm performance from Gunday et al. (2011). The Cronbach's alpha of each component was greater than .75. According to Nunnally's (1978) guidelines, all of the factors were reliable, respectively, financial performance (Cronbach α=.82) market performance (Cronbach α=.83), and export performance (Cronbach α=.91).

[3] The dataset was used in the second author's master thesis.

4. ANALYSIS AND RESULTS

The corporate features and profiles of the respondents were evaluated. 3 (5.26 percent) of the 57 firm responses were firm owners, 7 (12.28 percent) were department managers, 27 (47.36 percent) were top managers, and 20 (35.08 percent) were other positions. The age of firms ranges from 3 to 148 years, with an average age of 34.10. The range of personnel employed is from nine to two thousand. Automotive (12), textile (5), civil (5), chemistry (10), and machine (10) are among the principal industries of the companies (15). The industry 4.0 technologies that are most frequently implemented across all business activities are as follows: GPS (56 companies), smart devices (55), e-purchase (54 companies), mobile applications (53 companies), and IoT (49 firms). In all business operations, the mean number of industry 4.0 technologies utilized is as follows: mobile applications (8.50), smart devices (8.29), real time location technology (8.27), warehouse management systems (8.18), and GPS (8.19). In the realm of logistics, the prevailing industry 4.0 technologies are GPS (54 firms), smart devices (51 firms), mobile applications (50 firms), e-purchase (49 firms), and the Internet of Things (IoT) (46 firms). In the domain of logistics, the average utilization of Industry 4.0 technologies is as follows: e-purchase (7.73), GPS (7.40), warehouse management systems (7.34), mobile applications (7.32), and smart devices (7.21). The score for utilized industry 4.0 technology varied between 14 and 198 for firms, while the number of cars utilized in all company activities spanned from 5 to 21. (Max vehicles: 22, Grade: 0-10, Max Score: 220). Similarly, the score for utilized industry 4.0 technology varied from 5 and 157 for businesses, although the number of cars utilized in logistics alone spanned from 2 to 19. (Maximum of 22 cars (grades 0-10, maximum score 220)

Table 1 shows the descriptive statistics of DoL_4.0 and its six indicators:

Table 1. Descriptive Statistics of DoL_4.0 and its Six Indicators

	Minimum	Maximum	Range	Mean	Std. Deviation
Ind 1	0.06	0.90	Out of -1	0.47	0.19
Ind 2	0.23	0.95	Out of 1	0.65	0.24
Ind 3	0.02	0.71	Out of 1	0.32	0.14
Ind 4	0.09	0.86	Out of 1	0.49	0.19
Ind 5	0.64	9	Out of 10	4.73	1.95
Ind 6	0.23	7,14	Out of 10	3.24	1.45
DoL_4.0	1.52	19.47	Out of 24	9.91	3.98

Source: Own calculations

We conducted a correlation analysis between DoL 4.0 and export, financial, and market performance. Bivariate Pearson correlations between the constructs are presented in the correlation matrix found in Table 2. Positive correlations were observed between the variables DoL 4.0 and market performance ($r=0.45$; $p<0.01$), export performance ($r=0.38$; $p<0.01$), and financial performance ($r=0.46$; $p<0.01$).

Table 2. Correlation Analyses

	1	2	3	4
1.DoL_4.0	1			
2. Financial Perf.	.46**	1		
3. Market Perf.	.45**	.81**	1	
4. Export Perf.	.38**	.44**	.36**	1

** Correlation is significant at the 0.01 level; * Correlation is significant at the 0.05 level (2-tailed).

Source: Own calculations

5. FUTURE RESEARCH DIRECTIONS

Some of the shortcomings of this study indicate potential avenues for further investigation. In the first place, the research data was quite limited and was acquired solely from Turkish companies in Gaziantep, indicating the necessity to examine more sites. Statistical power would be increased for the model with a larger sample size, and future investigations may also consider implementing alternate sampling procedures. The sample was not categorized according to the firm sector (consideration of which could lead to clarified research results). Thirdly, convenience sampling was utilized, which restricts generalizability.

6. CONCLUSION

This investigation is conducted for exploratory purposes. While the primary objective of our study is not to investigate causal linkages, it does want to stimulate more conceptual and empirical research on DoL_4.0. The objective of this research is to construct a model that can quantify DoL_4.0.

Ali (2019) underscored the notion that organizations can obtain a competitive edge and mitigate supply chain risk with the increased adoption of industry 4.0 technologies. DoL_4.0 had a mean score of 9.91 out of 24. Our companies were required to invest in Logistics 4.0 technologies, according to the findings.

Correlation analyses indicated important findings. Our findings indicate that the implementation of Industry 4.0 technology will enhance the all three performance of companies. According to a study by Díaz-Chao et al. (2021), the implementation of Industry 4.0 technologies, including flexible production systems and robotics, had a beneficial impact on labor productivity, exports, and sales. Moreover, Oduro and De Nisco (2023) have shown that these technologies have a substantial and favorable impact on performance, encompassing both financial and non-financial aspects.

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