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Prioritizing the Digitalization Barriers: An AHP Application in the Turkish Logistics Industry*

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Abstract: *Digitalization has become an essential part of the logistics industry in the rapidly developing and changing environment. Considering the benefits that might provide to the logistics industry, revealing the barriers to digitalization has significant importance. In this study, barriers encountered in the transition to digital systems in the logistics sector in Turkey were prioritized with the Analytical Hierarchy Process method. According to the evaluations of ten experts, the barriers encountered are categorized under five groups as organizational, managerial, technical, financial, and the barriers arising from customer expectations. It has been determined that financial barriers were identified as the main barrier to the digitalization of the logistics industry. Technical barriers were determined in the second place, and barriers from customer expectations were the least prioritized barrier. With this exploratory study, it is expected to contribute to the literature by determining and prioritizing the barriers to digitalization in the Turkish logistics sector.*

Keywords: Digitalization, Barriers, Logistics, Logistics Industry, Analytical Hierarchy Process Method

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1. Introduction

In the globalizing world, the rise in the population, the spread of the free-market economy worldwide, communication and telecommunication networks and the demand for technology are increasing rapidly. With these developments, technology is an indispensable element in our daily lives, and there is no more suitable area than technology for reaching the communities (Gündebahar & Kuş-Khalilov, 2013: 453).

Digital transformation is expected to have a massive impact on different industries, industrial processes and even societies (Kagermann, 2014; Urbach et al., 2017; Vogelsang et al., 2019). In the business environment, digitalization is a process that includes perception and management beyond the digitalization of data or data sources. The digitalization of a business is not limited to transferring processes that were previously managed manually or by analogue methods to digital media, also transferring to a computer environment. In addition to this, it also includes using the new opportunities offered by this environment and correctly managing new problems which are specific to this environment (Fichman et al., 2014).

The Covid-19 outbreak in the beginning of 2020 caused some disruptions in supply chains. However, it also brought many opportunities. Thanks to this process, the importance of digitalization for the logistics

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industry has emerged and issues such as remote working, the use of electronic documents in business processes and the spread of related software have played an important role. Accordingly, Herold et al. (2021) examined new insights into the reactions and lessons learned with regard to the Covid-19 pandemic in terms of logistics service providers.

Post millennium period characterized as "the digital age" (Hirt & Willmott, 2014), has capital importance in enhancing logistics services and sharply changed the competitive dynamics of the logistics service industry (Evangelista & Sweeney, 2006: 56; Hofmann & Osterwalder, 2017). Several market developments force logistics service providers to adopt new technologies continuously (Mathauer & Hofmann, 2019: 416). The logistics industry, which is shown as one of the three sectors that will develop in the world in the 21st century, is open to development and affected by innovations in information and communication technologies. With the rapid development in technology, logistics companies cannot remain indifferent to these developments to meet customer demands and needs because of the intensely competitive environment (Gülenç & Karagöz, 2008: 74). Therefore, identifying and weighting the barriers to digitalization is crucial for the development of the logistics industry. From this point of view, this research aims to prioritize the barriers encountered in the transition to digital systems in the Turkish logistics sector. Therefore, in the first stage of the study semi-structured interviews were conducted for revealing the barriers of digitalization in the logistics industry. Accordingly, Analytical Hierarchy Process (AHP) method was conducted for the weighting the obtained barriers.

The following section introduces the relevant literature based on digitalization barriers in the logistics sector. The third section describes the methodology of the study. In the fourth section, results of the AHP research are presented. In the fifth and the last section, the results are discussed concerning similar studies in the literature.

2. Literature Review

Academic literature on digitalization in logistics focuses on more specific digitalization-related topics (Hofmann & Osterwalder, 2017: 2). When the literature is examined, it can be seen that prior studies emphasized the importance of digitalization processes. After that, in recent years, studies have intensified in industry 4.0 and logistics 4.0 subjects.

Gülenç and Karagöz (2008) investigated how logistics firms are affected by electronic applications in their activities. Results of the study emphasized the scope and importance of e-logistics activities. Digitalization in the logistics sector has many benefits, such as ensuring customer satisfaction for companies, providing flexibility in the ordering system, reducing the level of inventory in warehouses. The authors also stated that logistics firms do not attach the necessary importance to e-logistics activities. However, it is thought that it will have a significant impact on the competitiveness of the logistics industry. In the current situation, information technologies are seen as an additional cost to businesses, but these activities will become a necessity in the future. In another study, Görçün (2018) evaluated how the robots and robotic systems will be functional and what will be happening in the future of the logistics industry. According to Görçün (2018), robots are used limitedly as expensive semi-autonomous systems for now, but robots will become the most important component of faster, effective, and optimized logistics processes. Especially in the future, there will be no labour force for any work that robots can do in warehouses and distribution centers. Öztemel and Gürsev (2018) examined the Industry 4.0 concept and the impact of innovations on logistics management in their study with the help of questionnaire research. Results showed that technologies such as the internet of things, robotics, data mining, warehouse automation systems are sufficient to meet the needs of the logistics industry as components of Industry 4.0. Cyber-physical systems, 3D printers and other technologies in Industry 4.0 models are not effective and efficient for the logistics industry. Aylak et al. (2020) investigated the technological trends in the logistics sector in Turkey via a survey with 65 companies, including different technologies, logistics, services, IT supply and retail sectors. According to the study results, the main trends in the logistics sector in Turkey are supergrid logistics, autonomous logistics, robotics and automation, the internet of things, cloud logistics, big data and e-commerce.

Also, some studies are investigated barriers and benefits to the digitalization of the logistics industry. For example, Lai et al. (2005) identified the benefits and barriers to adopting information technology to the Hong Kong logistics industry. In the study questionnaire was conducted to the logistics service providers in Hong Kong and the study revealed that lack of expertise in information technology was the most emphasized barrier. Besides, particular studies focused only the barriers to the digitalization. Töytäri et al. (2017) explored the barriers in adopting smart services among six globally operating European industrial and technology companies by conducting a multi-case study. They classified the barriers into internal barriers, resource and capability gaps and external barriers. Results of the study showed that the biggest set of barriers seems to lie in the resources and capabilities, specifically, the lack of managerial cognition of reconfiguration and disengagement. Similarly, Kane et al. (2018) investigated the challenges and opportunities of using social and digital business. In the study, the survey was conducted to the various companies from 123 countries and 28 industries. The authors determined the barriers as competency traps, lack of experimentation and iteration, dealing with ambiguity and constant change, buying and implementing the right technology and lack of organizational support to develop employee's skills. Moreover, Vogelsang et al. (2019) identified key barriers to digitalization for manufacturing firms by conducting semi-structured interviews and categorized them as missing skills, technical barriers, individual barriers, organizational and cultural barriers and environmental barriers. Cichosz et al. (2020) identified five main barriers to digitalization for large logistics service providers in Poland, following the multicase study approach. They found out barriers and organizational elements with the associated leading practices for successful digitalization of the logistics industry. According to the results, the main barriers are the complexity of the logistics network and the lack of resources. In addition, Kern (2021) overviewed current status of digitalization across logistics infrastructure (seaports, airports, warehousing), logistics execution (road transport, sea transport, air transport, and courier, express, and parcel delivery), and logistics services and advisory. Results showed that major barriers for digitalization of logistics areas are the high upfront investments, operational challenges (for instance, which business case to define and poor data quality), and a mindset that is still focused on traditional business models). Lastly, Gan et al. (2022) examined the logistics industry, digitalization, and ecological civilization, as well as the barriers in China's ecological civilization pilot provinces. According to the results, obstacle factors are mainly focused on the level of digitalization benefits, social ecological civilization, and ecological environment indicators.

When the relevant literature is examined, it can be seen that AHP method was used in similar studies. For example, Zekhnini et al. (2020) investigated key supply chains 4.0 risks and examined the relationship between them. Also, Gupta et al. (2021) determined important factors for manpower readiness for digitization of logistics operations. Moreover, authors prioritized the identified factors and created the readiness index. In addition, Adem et al. (2021) identified ten different performance indicators related with unmanned aerial vehicles in terms of industry 4.0 in the logistics industry.

In addition, it is seen that the AHP method is frequently used in determining the barriers observed in the logistics sector. For example, Bouzon et al. (2016) analyzed reverse logistic barriers with fuzzy Delphi method and AHP. Moreover, Biswas and Das (2020) identified the five essential barriers of supply chain management in Indian manufacturing sector with fuzzy-AHP method. Also, Sah et al. (2021) examined barriers to implement drone logistics by using the fuzzy Delphi method and AHP.

Within the framework of the Turkish sample, although there are work-related studies on the effects of industry 4.0 and the advantages and disadvantages of digitalization in the logistics sector, it is not encountered the studies focusing specifically on barriers. Therefore, this study is expected to contribute to the literature in this respect.

3. Methodology

Multi-criteria decision making is the application of relevant methods and procedures to select, rank or classify the best potential decision options based on often conflicting tangible and intangible criteria or attributes. The main purpose of multi-criteria decision-making methods is to suggest the best to decision-makers (Guitouni & Martel, 1998: 502). AHP is one of the most important of these methods.

Thomas L. Saaty developed the AHP method in 1977 to solve complex problems. It is the most widely used multi-criteria decision-making method for solving many economic, social and technical problems. AHP is a technique that ranks the decision options in order of importance within the criteria determined by the decision-maker among many options. AHP is a systematic structure in which many decision-makers can be included in the process. AHP is a linear weighted method that can evaluate quantitative and qualitative criteria in decision-making, including the preferences, experiences, and knowledge of groups or individuals in the decision process (Saaty, 1980; Özbek & Eren, 2013: 48). For this reason, the barriers obtained from the interviews and relevant literature were weighted with the AHP method in this study.

In the AHP method, expert opinions are needed to determine the importance of the criteria. For this, the decision-makers compare the criteria with each other in the evaluation form, which is prepared using Saaty's 1-9 scale specified in Table 1. This scale lists the priorities of the decision alternatives (Saaty, 1999).

Table 1. Importance Rating Table Used in Comparisons

Importance Rating	Definition	Statement
1	Equally Important	Both factors have the same precaution.
3	Important in Middle Grade (Less Superior)	According to experience and judgment, one factor is more important than another.
5	Important in Strong Grade (Superior State)	One factor is strongly more important than the other.
7	Important in Very High Grade (Very Superior State)	One factor is strongly more important at a higher level than the other.
9	Important in Absolute Grade (Absolute Superiority)	One of the factors is very important to the other.
2,4,6,8	Intermediate Values	The preference between the two factors is the intermediate values of the ratios found in the above explanations.
Mutual Values	If factor i has one of the above numbers assigned to it when compared to factor j (x), then j has the reciprocal value when compared with i (1/x).	

Source: Saaty, 1977: 99; Vaidya & Kumar, 2006: 2.

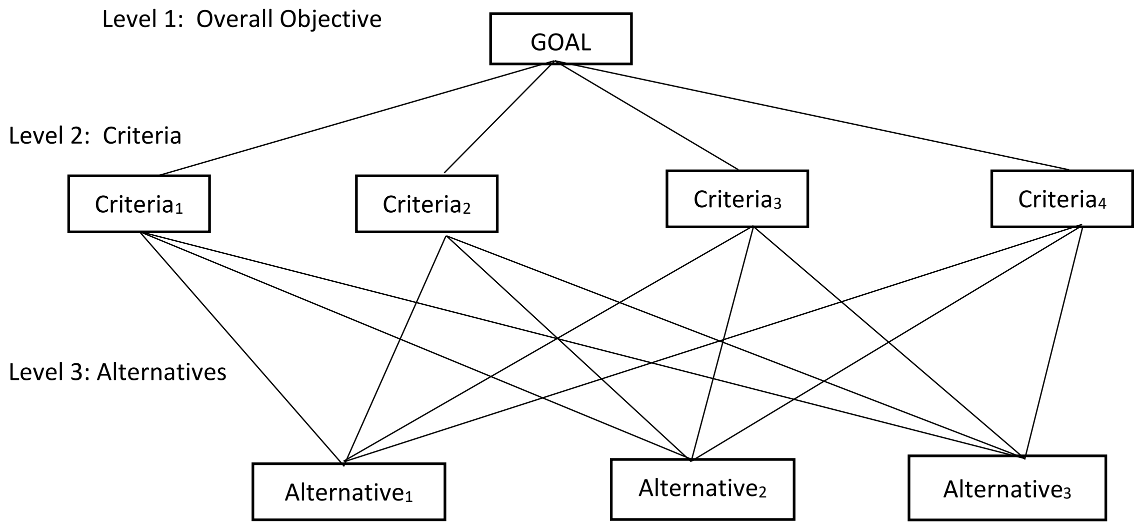
After determining the problem and related criteria in the AHP method, the hierarchical structure of the decision problem was created. After that binary comparison of the criteria for each level of the hierarchy and determination of the importance of the criteria by taking advantage of the eigenvectors were implemented. In the last steps, compliance rates were calculated, alternatives sorted according to their relative priority values, and the alternative with the highest priority value was chosen (Özbek & Eren, 2013: 49).

The general hierarchy structure of the AHP method is shown in Figure 1. As shown in Figure 1, the hierarchy starts with a clearly stated purpose, continues with the criteria that can directly affect the said purpose and their sub-criteria, and ends with the alternatives to be selected (Murat & Çelik, 2007). The problem hierarchy of the study, which is based on the general hierarchical structure of the AHP method, is shown in Figure 2.

As stated in Figure 2, the study aims to determine the importance and priority of the barriers encountered in the digitalization of the logistics sector. Thus, the study was carried out in two stages. In the first stage of the study, semi-structured interviews were conducted with 19 experts working in the logistics sector in managerial positions between the dates of 1 June-1 September 2020. While selecting the participants, attention was paid to their sector experience and knowledge on the subject. Accordingly, relevant literature was searched to determine the logistics sector's digitalization barriers. Digitalization barriers obtained from interviews and literature review has been examined in five main dimensions as managerial, organizational, technical, financial and barriers from customer expectations which is shown in

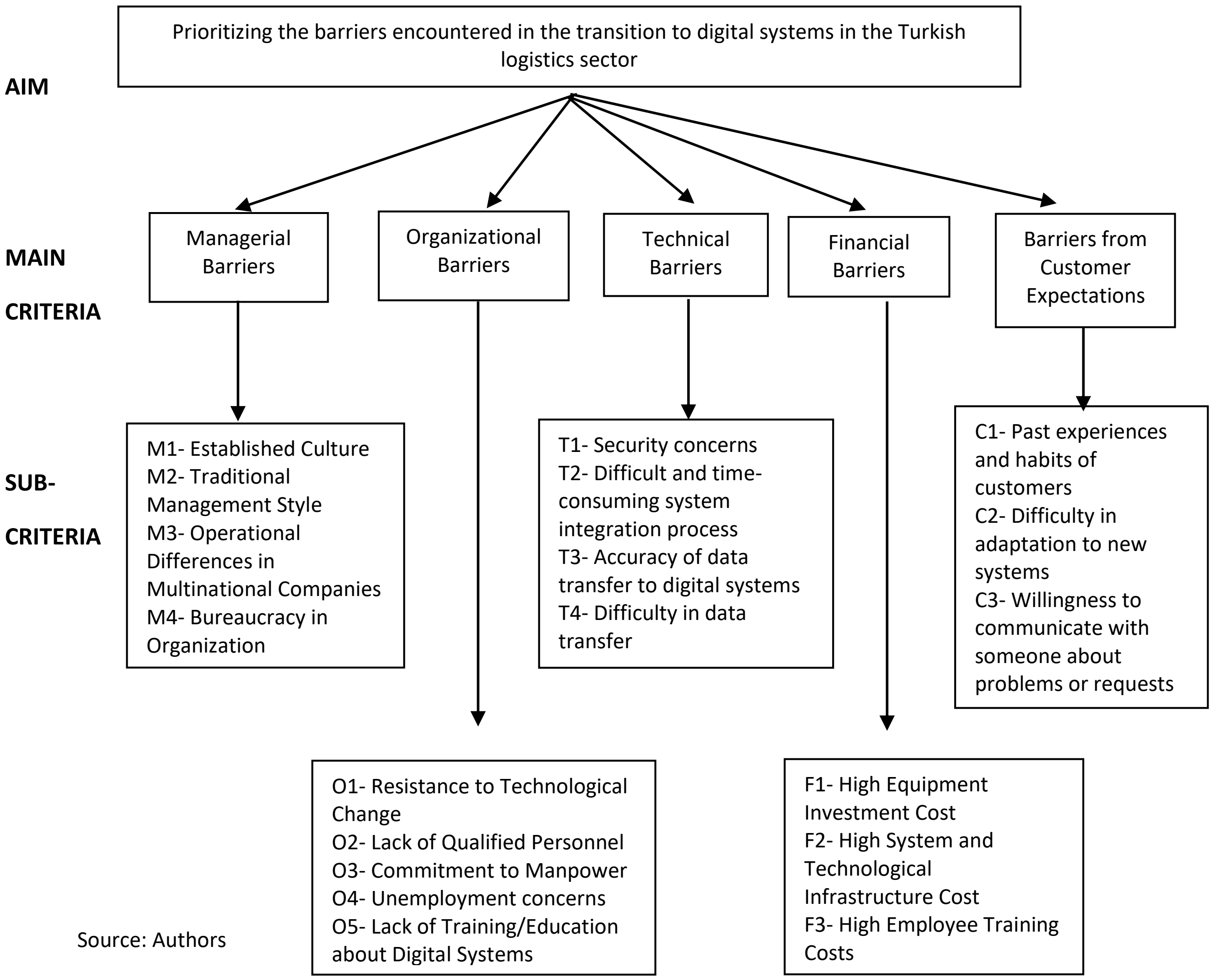
Table 2. The digitalization barriers for the Turkish logistics sector shown in Table 2 have been accepted as the sub-criteria of the decision hierarchy shown in Figure 2.

Figure 1. General Hierarchy Structure of the AHP Method



Source: Adapted from Saaty 1990, 1991.

Figure 2. Problem Hierarchy



Source: Authors

In the second stage of the study, AHP method was used while evaluating the importance and priority ranking of the digitalization barriers shown in Table 2. Since the results in the AHP method are based on the judgments of the experts included in the study, it is expected that the experts should have adequate knowledge on the subject for consistent results (Saaty, 2000). Accordingly, the data collection form prepared within the scope of the study was evaluated by 10 experts whose fields of expertise are shown in Table 3.

Table 2. Digitalization Barriers for the Turkish Logistics Sector

Dimensions	Digitalization Barriers	Source
Managerial	Established Culture	Lai et al. (2005), Töytäri et al. (2017), Interviews
	Traditional Management Style	Vogelsang et al. (2019), Interviews
	Operational Differences in Multinational Companies	Interviews
	Bureaucracy in Organization	Töytäri et al. (2017), Interviews
Organizational	Resistance to Technological Change	Hadjimanolis (1999), Cichosz et al. (2020), Vogelsang et al. (2019), Evangelista and Sweeney (2006), Interviews
	Lack of Qualified Personnel	Hadjimanolis (1999), Cichosz et al. (2020), , Kane et al. (2018), Lai et al. (2005), Interviews
	Commitment to Manpower	Interviews
	Unemployment concerns	Vogelsang et al. (2019), Interviews
	Lack of Training/Education about Digital Systems	Evangelista and Sweeney (2006), Kilpala et al. (2005), Interviews
Technical	Security concerns	Cichosz et al. (2020), Evangelista and Sweeney (2006), Vogelsang et al. (2019), Interviews
	Difficult and time-consuming system integration process	Kane et al. (2018), Cichosz et al. (2020), Interviews
	Accuracy of data transfer to digital systems	Interviews
	Difficulty in data transfer	Interviews, Lai et al. (2005)
Financial	High Equipment Investment Cost	Evangelista and Sweeney (2006), Vogelsang et al. (2019), Interviews
	High System and Technological Infrastructure Cost	Hadjimanolis (1999), Evangelista and Sweeney (2006), Lai et al. (2005), Interviews
	High Employee Training Costs	Dredge et al. (2018), Interviews
Customer Expectations	Past experiences and habits of customers	Hadjimanolis (1999), Interviews
	Difficulty in adaptation to new systems	Evangelista and Sweeney (2006), Interviews
	Willingness to communicate with someone about problems or requests	Töytäri et al. (2017), Interviews

Source: Authors

In the second stage of the study, due to time constraint and effects of the Covid-19 pandemic, an AHP study was conducted with 10 participants. As shown in detail in Table 3, all experts are experienced in the logistics sector. Four of them are in the general manager position, and five are working in the operation department. In order to increase the consistency of the study, attention was paid to ensure that the experts have at least 10 years of experience in the logistics industry. After the AHP application, calculations were made using the Microsoft Office Excel program. All participant answers are considered equally important.

Table 3. Details of the Experts

Participant	Age	Education	Department	Position	Total Sector Experience	Total Logistics Sector Experience
1	37	Bachelor Degree	International Supply Chain	General Manager	15 Years	15 Years
2	35	Bachelor Degree	Business Development	Operation Manager	13 Years	11 Years
3	36	Bachelor Degree	Forwarder	General Manager	19 Years	17 Years
4	38	Bachelor Degree	Export Operation	Operation Specialist	15 Years	13 Years
5	35	Bachelor Degree	Sea Operation	Operation Specialist	10 Years	10 Years
6	43	Master Degree	Management	General Manager	25 Years	25 Years
7	36	Bachelor Degree	Export	Operation Specialist	12 Years	10 Years
8	31	Bachelor Degree	Logistics – Project Cargo	Customer Relations Specialist	10 Years	10 Years
9	34	Bachelor Degree	Sales & Marketing	General Manager	15 Years	13 Years
10	39	Bachelor Degree	Operation	Operation Manager	18 Years	15 Years

4. Findings

In this section of the study, AHP results were illustrated according to the main digitalization barriers.

4.1. Weights of Managerial Barriers to Digitalization

The decision matrix, which is the first step of the AHP method, was created to weigh the managerial barriers to digitalization. The decision matrix is shown in Table 4.

Table 4. The Pairwise Comparison Matrix for Managerial Barriers

	M1	M2	M3	M4
M1	1	0.6230	2.2790	1.0644
M2	1.6049	1	2.2901	1.2589
M3	0.4387	0.4366	1	0.5285
M4	0.9394	0.7943	1.8920	1
TOTAL	3.9832	2.8540	7.4612	3.8518

After the pairwise comparison matrix was created, the values in the matrix were normalized. The normalized matrix is shown in Table 5.

Table 5. Normalized Matrix for Managerial Barriers

	M1	M2	M3	M4	Priority Weight
M1	0.2510	0.2183	0.3054	0.2763	0.2627
M2	0.4029	0.3503	0.3069	0.3268	0.3467
M3	0.1101	0.1529	0.1340	0.1372	0.1335
M4	0.2358	0.2783	0.2535	0.2596	0.2568
TOTAL	1	1	1	1	1

The "Priority Weight" column obtained by averaging the rows of the normalized matrix shows the priorities vector regarding the managerial barriers. According to the results of the AHP analysis, the order of importance and priority of the managerial barriers are shown below:

1. Traditional Management Style (M2: 0.3467)

2. Established Culture (M1: 0.2627)

3. Bureaucracy in Organization (M4: 0.2568)

4. Operational Differences in Multinational Companies (M3: 0.1335)

After obtaining the importance and priority order of the criteria, the AHP consistency ratio was calculated to analyze the consistency of the results. It is indicated by the consistency ratio (CR) and calculated with the following equation;

$$CR = \frac{CI}{RI} \quad (1)$$

The CI value in the above equation represents the consistency index and is calculated with the equation:

$$CI = \frac{\lambda\text{max} - n}{n-1} \quad (2)$$

The RI value in the same equation expresses the Random Index and takes value according to the "n" number. In order to accept that the obtained matrix is consistent, CR<0.10 is required, and it is accepted that the consistency increases as the CR gets closer to zero (Önder & Önder, 2015). RI values up to n=11 are shown in Table 6.

Table 6. Random Index

n	1	2	3	4	5	6	7	8	9	10	11
RI	0	0	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49	1.51

Source: Önder & Önder, 2015: 34.

In order to replace the consistency indicator in the calculation formula, the value of λ_{max} was found by dividing all the priorities matrix by the priorities vector and averaging the obtained values. Accordingly, all the priorities matrix of the managerial barriers is shown in Table 7.

Table 7. Priority Matrix of Managerial Barriers

	M1	M2	M3	M4	TOTAL
M1	0.2627	0.2160	0.3044	0.2733	1.0567
M2	0.4217	0.3467	0.3059	0.3233	1.3978
M3	0.1153	0.1514	0.1335	0.1357	0.5360
M4	0.2468	0.2754	0.2527	0.2568	1.0319

The process of dividing all the priorities matrix by the priorities vector is shown in Table 8.

Table 8. Division of All Priorities Matrix into Priority Vector of Managerial Barriers

All Priorities Matrix (X)	Priority Vector (Y)	X/Y
1.0567	0.2627	4.0211
1.3978	0.3467	4.0310
0.5360	0.1335	4.0125
1.0319	0.2568	4.0178

$$\lambda_{max} = \frac{4.0211+4.0310+4.0125+4.0178}{4}$$

$$\lambda_{max} = 4.0206$$

$$\text{where; } CI = \frac{4.0206-4}{3} = 0.0068$$

$$\text{where; } CR = \frac{CI}{RI} = \frac{0.0068}{0.9} = 0.0076$$

Since 0.0076 is <0.10, it has been accepted that the results regarding the importance and priority ranking of the managerial barriers shown in Table 8 are valid and consistent.

4.2. Weights of Organizational Barriers to Digitalization

The decision matrix, the first step of the AHP method, was also created to weigh the strategies related to the organizational barriers. The decision matrix is shown in Table 9.

Table 9. The Pairwise Comparison Matrix for Organizational Barriers

	O1	O2	O3	O4	O5
O1	1	2.5831	1.1375	2.2424	0.7767
O2	0.3871	1	1.0524	2.2754	0.4094
O3	0.8790	0.9502	1	2.2143	0.5248
O4	0.4459	0.4394	0.4515	1	0.6187
O5	1.2873	2.4425	1.9051	1.6160	1
TOTAL	3.9994	7.4154	5.5467	9.3483	3.3298

After the decision matrix was created, the values in the matrix were normalized. The normalized matrix is shown in Table 10.

Table 10. Normalized Matrix for Organizational Barriers

	O1	O2	O3	O4	O5	Priority Weight
O1	0.2500	0.3483	0.2050	0.2398	0.2332	0.2553
O2	0.0967	0.1348	0.1897	0.2434	0.1229	0.1575
O3	0.2197	0.1281	0.1802	0.2368	0.1576	0.1845
O4	0.1114	0.0592	0.0814	0.1069	0.1858	0.1089
O5	0.3218	0.3293	0.3434	0.1728	0.3003	0.2935
TOTAL	1	1	1	1	1	1

The "Priority Weight" column obtained by averaging the rows of the normalized matrix shows the priorities vector regarding the organizational barriers. According to the results of the AHP analysis, the order of importance and priority of the organizational barriers are shown below:

1. Lack of Training/Education about Digital Systems (O5: 0.2935)

2. Resistance to Technological Change (O1: 0.2553)

3. Commitment to Manpower (O3: 0.1845)

4. Lack of Qualified Personnel (O2: 0.1575)

5. Unemployment Concerns (O4: 0.1089)

After obtaining the importance and priority order of the criteria, all the priorities matrix created to analyze the consistency of the results are shown in Table 11.

Table 11. All Priority Matrix of Organizational Barriers

	O1	O2	O3	O4	O5	TOTAL
O1	0.2553	0.4069	0.2099	0.2444	0.2280	1.3447
O2	0.0988	0.1575	0.1942	0.2480	0.1201	0.8188
O3	0.2244	0.1497	0.1845	0.2413	0.1540	0.9541
O4	0.1138	0.0692	0.0833	0.1089	0.1816	0.5570
O5	0.3286	0.3848	0.3515	0.1761	0.2935	1.5348

The process of dividing all the priorities matrix by the priorities vector is shown in Table 12.

Table 12. Division of All Priorities Matrix into Priority Vector of Organizational Barriers

All Priorities Matrix (X)	Priority Vector (Y)	X/Y
1.3447	0.2553	5.2666
0.8188	0.1575	5.1972
0.9541	0.1845	5.1703
0.5570	0.1089	5.1111
1.5348	0.2935	5.2278

$$\lambda_{max} = \frac{5.2666+5.1972+5.1703+5.1111+5.2278}{5}$$

$$\lambda_{max} = 5.1946$$

$$\text{where; } CI = \frac{5.1946-5}{4} = 0.0486$$

$$\text{where; } CR = \frac{CI}{RI} = \frac{0.0486}{1.12} = 0.0434$$

Since 0.0434 is <0.10, it has been accepted that the results regarding the importance and priority ranking of the organizational barriers shown in Table 12 are valid and consistent.

4.3. Weights of Technical Barriers to Digitalization

The decision matrix, the first step of the AHP method, was also created to weigh the strategies related to the technical barriers.

The decision matrix is shown in Table 13.

Table 13. The Pairwise Comparison Matrix for Technical Barriers

	T1	T2	T3	T4
T1	1	0.7943	0.6506	0.7904
T2	1.2589	1	2.5312	2.4664
T3	1.5368	0.3950	1	0.9951
T4	1.2650	0.4054	1.0048	1
TOTAL	5.0608	2.5948	5.1868	5.2520

After the decision matrix was created, the values in the matrix were normalized. The normalized matrix is shown in Table 14.

Table 14. Normalized Matrix for Technical Barriers

	T1	T2	T3	T4	Priority Weight
T1	0.1975	0.3061	0.1254	0.1505	0.1949
T2	0.2487	0.3853	0.4880	0.4696	0.3979
T3	0.3036	0.1522	0.1927	0.1894	0.2095
T4	0.2499	0.1562	0.1937	0.1904	0.1975
TOTAL	1	1	1	1	1

The "Priority Weight" column obtained by averaging the rows of the normalized matrix shows the priorities vector regarding the technical barriers. According to the results of the AHP analysis, the order of importance and priority of the technical barriers are shown below:

1. Difficult and time-consuming system integration process (T2: 0.3979)
2. Accuracy of data transfer to digital systems (T3: 0.2095)
3. Difficulty in data transfer (T4: 0.1975)
4. Security concerns (T1: 0.1949)

After obtaining the importance and priority order of the criteria, all the priorities matrix created to analyze the consistency of the results are shown in Table 15.

Table 15. All Priority Matrix of Technical Barriers

	T1	T2	T3	T4	TOTAL
T1	0.1949	0.3160	0.1363	0.1561	0.8035
T2	0.2453	0.3979	0.5304	0.4873	1.6611
T3	0.2995	0.1572	0.2095	0.1966	0.8629
T4	0.2465	0.1613	0.2105	0.1975	0.8160

The process of dividing all the priorities matrix by the priorities vector is shown in Table 16.

Table 16. Division of All Priorities Matrix into Priority Vector of Technical Barriers

All Priorities Matrix (X)	Priority Vector (Y)	X/Y
0.8035	0.1949	4.1225
1.661	0.3979	4.1742
0.8629	0.2095	4.1181
0.8160	0.1975	4.1302

$$\lambda_{max} = \frac{4.1225+4.1742+4.1181+4.1302}{4}$$

$$\lambda_{max} = 4.1362$$

$$\text{where; } CI = \frac{4.1362-4}{3} = 0.0454$$

$$\text{where; } CR = \frac{CI}{RI} = \frac{0.0454}{0.9} = 0.0504$$

Since 0.0504 is <0.10, it has been accepted that the results regarding the importance and priority ranking of the technical barriers shown in Table 16 are valid and consistent.

4.4. Weights of Financial Barriers to Digitalization

The decision matrix, the first step of the AHP method, was also created to weigh the strategies related to the financial barriers. The decision matrix is shown in Table 17.

Table 17. The Pairwise Comparison Matrix for Financial Barriers

	F1	F2	F3
F1	1	0.4258	2.3570
F2	2.3484	1	2.2441
F3	0.4242	0.4456	1
TOTAL	3.7727	1.8714	5.6011

After the decision matrix was created, the values in the matrix were normalized. The normalized matrix is shown in Table 18.

Table 18. Normalized Matrix for Financial Barriers

	F1	F2	F3	Priority Weight
F1	0.2650	0.2275	0.4208	0.3044
F2	0.6224	0.5343	0.4006	0.5191
F3	0.1124	0.2381	0.1785	0.1763
TOTAL	1	1	1	1

The "Priority Weight" column obtained by averaging the rows of the normalized matrix shows the priorities vector regarding the financial barriers. According to the results of the AHP analysis, the order of importance and priority of the financial barriers are shown below:

1. High System and Technological Infrastructure Cost (F2: 0.5191)
2. High Equipment Investment Cost (F1: 0.3044)
3. High Employee Training Costs (F3: 0.1763)

After obtaining the importance and priority order of the criteria, all the priorities matrix created for the analysis of the consistency of the results are shown in Table 19.

Table 19. All Priority Matrix of Financial Barriers

	F1	F2	F3	TOTAL
F1	0.3044	0.2210	0.4156	0.9412
F2	0.7150	0.5191	0.3957	1.6299
F3	0.1291	0.2313	0.1763	0.5368

The process of dividing all the priorities matrix by the priorities vector is shown in Table 20.

Table 20. Division of All Priorities Matrix into Priority Vector of Financial Barriers

All Priorities Matrix (X)	Priority Vector (Y)	X/Y
0.9412	0.3044	3.0914
1.6299	0.5191	3.1396
0.5368	0.1763	3.0441

$$\lambda_{max} = \frac{3.0914+3.1396+3.0441}{3}$$

$$\lambda_{max} = 3.0917$$

$$\text{where; } CI = \frac{3.0917-3}{2} = 0.0458$$

$$\text{where; } CR = \frac{CI}{RI} = \frac{0.0458}{0.58} = 0.0790$$

Since 0.0790 is <0.10, it has been accepted that the results regarding the importance and priority ranking of the financial barriers shown in Table 20 are valid and consistent.

4.5. Weights of Barriers from Customer Expectations

The decision matrix, which is the first step of the AHP method, was also created to weigh the strategies related to barriers from customer expectations. The decision matrix is shown in Table 21.

Table 21. The Pairwise Comparison Matrix for Barriers from Customer Expectations

	C1	C2	C3
C1	1	1.2972	1.6298
C2	0.7708	1	0.7892
C3	0.6135	1.2670	1
TOTAL	2.3843	3.5643	3.4190

After the decision matrix was created, the values in the matrix were normalized. The normalized matrix is shown in Table 22.

Table 22. Normalized Matrix for Barriers from Customer Expectations

	C1	C2	C3	Priority Weight
C1	0.4193	0.3639	0.4766	0.4200
C2	0.3232	0.2805	0.2308	0.2782
C3	0.2573	0.3554	0.2924	0.3017
TOTAL	1	1	1	1

The "Priority Weight" column obtained by averaging the rows of the normalized matrix shows the priorities vector regarding the barriers from customer expectations. According to the results of the AHP analysis, the order of importance and priority of the barriers from customer expectations are shown below:

1. Past experiences and habits of customers (C1: 0.4200)

2. Willingness to communicate with someone about problems or requests (C3: 0.3017)

3. Difficulty in adaptation to new systems (C2: 0.2782)

After obtaining the importance and priority order of the criteria, all the priorities matrix created for the analysis of the consistency of the results are shown in Table 23.

Table 23. All Priority Matrix for Barriers from Customer Expectations

	C1	C2	C3	TOTAL
C1	0.4200	0.3609	0.4918	1.2727
C2	0.3237	0.2782	0.2381	0.8401
C3	0.2576	0.3525	0.3017	0.9119

The process of dividing all the priorities matrix by the priorities vector is shown in Table 24.

Table 24. Division of All Priorities Matrix into Priority Vector of Barriers from Customer Expectations

All Priorities Matrix (X)	Priority Vector (Y)	X/Y
1.2727	0.4200	3.0303
0.8401	0.2782	3.0196
0.9119	0.3017	3.0222

$$\lambda_{max} = \frac{3.0303+3.0196+3.0222}{3}$$

$$\lambda_{max} = 3.0240$$

$$\text{where; } CI = \frac{3.0240-3}{2} = 0.0120$$

$$\text{where; } CR = \frac{CI}{RI} = \frac{0.0120}{0.58} = 0.0207$$

Since 0.0207 is <0.10, it has been accepted that the results regarding the importance and priority ranking of the Barriers from Customer Expectations shown in Table 24 are valid and consistent.

4.6. Weights of Main Barriers to Digitalization

The decision matrix was also created to weigh the main barriers to the digitalization of logistics companies. The decision matrix is shown in Table 25.

Table 25. The Pairwise Comparison of Main Criteria

	MB	OB	TB	FB	CB
MB	1	1.7711	0.6261	0.5026	2.3418
OB	0.5646	1	1.0844	1.0814	2.0982
TB	1.5971	0.9221	1	1.1552	1.5772
FB	1.9896	0.9247	0.8656	1	1.7503
CB	0.4270	0.4765	0.6340	0.5712	1
TOTAL	5.5783	5.0945	4.2102	4.3105	8.7676

After the decision matrix was created, the values in the matrix were normalized. The normalized matrix is shown in Table 26.

Table 26. Normalized Matrix of Main Criteria

	MB	OB	TB	FB	CB	MEAN
MB	0.1792	0.3476	0.1487	0.1165	0.2671	0.2118
OB	0.1012	0.1962	0.2575	0.2508	0.2393	0.2090
TB	0.2863	0.1809	0.2375	0.2680	0.1798	0.2305
FB	0.3566	0.1815	0.2055	0.2319	0.1996	0.2350
CB	0.0765	0.0935	0.1505	0.1325	0.1140	0.1134
TOTAL	1	1	1	1	1	1

The "Priority Weight" column obtained by averaging the rows of the normalized matrix shows the priorities vector regarding the main barriers. According to the results of the AHP analysis, the order of importance and priority of the main barriers are shown below:

1. Financial Barriers (FB: 0.2350)

2. Technical Barriers (TB: 0.2305)

3. Managerial Barriers (MB: 0.2118)

4. Organizational Barriers (OB: 0.2090)

5. Barriers from Customer Expectations (CB: 0.1134)

Since CR 0.0481 is <0.10, it has been accepted that the results regarding the importance and priority ranking of the main barriers.

5. Conclusion

Digitalization is one of the primary developments that will change society and business in the near and far future. It is expected that the logistics sector will also be affected by these developments. Besides decreasing manual work, digitalized logistics operations reveal new ways of optimizing the logistics processes and allow the real-time monitoring of transportation flows. Considering all these issues, it is crucial to identify the barriers to digitalization. For this reason, this study aims to prioritize the barriers encountered in the transition to digital systems in the Turkish logistics sector.

As a result of the study, which included semi-structured interviews and AHP method digitalization barriers were determined into five main dimensions as managerial, organizational, technical, financial and barriers from customer expectations. According to the results, financial barriers have been identified as the main barrier to digitalization. After that, technical barriers were determined in the second place. Barriers from customer expectations were the least prioritized barrier. This situation shows that customers are ready for the digitalization of the logistics industry and the digitalization process will result in success for all stakeholders when the physical and technical barriers are overcome. High system and technological infrastructure costs became prominent when the financial barriers were examined. This situation shows that investing in technological devices and establishing the necessary system poses a challenge for logistics companies at the first stage. Therefore, companies with strong financial infrastructure are one step ahead of other companies in digitalization. In terms of technical barriers, difficult and time-consuming system integration process and accuracy of data transfer to digital systems come to the forefront. This indicates that integration with digital systems seems a toilsome process for the logistics industry, and there are some concerns about the accuracy of digital systems, such as cyber security. The high priority of the traditional management style and the established culture among the managerial barriers also support these concerns. Besides, identifying the lack of training and education about digital systems as an important barrier among organizational barriers indicates that there is still a training gap in the use of digital systems and technology. Also, past experiences and habits of customers became forefront in the barriers from customer expectations.

When the relevant literature is examined, there are so many barriers that were determined similarly. For example, Lai et al. (2005) investigated Hong Kong's logistics industry in terms of digitalization benefits and barriers. In their study, while financial barriers ranked third in order of importance, financial barriers determined as the most important barrier in this study. Moreover, resistance to change and keeping traditional roles determined as similar barriers in both studies. Cichosz et al. (2020) examined barriers and success factors of digital transformation with the sample of nine international and global logistics service providers. Most of the barriers, which are lack of qualified personnel, resistance to change, data protection and security and adaption to new systems, identified by Cichosz et al. are parallel with this study. In another study from manufacturing sector, Vogelsang et al. (2019) identified five main barriers as missing skills, technical barriers, individual barriers, organizational and cultural barriers and environmental barriers. In this study, environmental barriers which include lack of standards and laws were not mentioned by the participants. Although the names of the other main barriers differ, similar findings were obtained in the contents of the barriers. Töytäriet al. (2017) explored the barriers in adopting smart services among six global industrial companies and categorized the barriers under three headings which are internal barriers, external barriers and resource and capability gaps. Management culture from internal barriers and lack of resources from resource gaps were designated as similar to this study. However, none of the external barriers were detected in this study. Apart from the barriers in the literature, operational differences in multinational companies and accuracy in data transfer were identified as barriers of digitalization in this study.

The barriers encountered in the transition to digital systems in the Turkish logistics sector were revealed and prioritized in this study. The study's outputs are expected to be beneficial to logistics companies on the way to digitization. However, the study has some limitations. Because of the intense working conditions in the logistics industry and Covid-19 pandemic restrictions, the study was carried out with a limited sample. Thus, various results can be achieved by different sample selection. In future studies, it is recommended to expand the sample and combine different multi-criteria decision-making methods. Moreover, it might be useful to deeply examine some of the issues uncovered in the study, such as reasons for resistance to technological change and what kind of training is needed in the transition to digital systems.

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