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Barriers in Sustainable Lean Supply Chain Management: Implementation in SMEs

Ebru TAKCI[1], Erhan ADA[2], Yiğit KAZANÇOĞLU[3]

ABSTRACT

As the world undergoes significant transformations in various domains, including technology, energy supply and communication, the idea of sustainability has become a significant issue. This study investigates the barriers to Sustainable Lean Supply Chain (SLSC) management within Small and Medium-Sized Enterprises (SMEs) and explores the structural interrelationships among these barriers. A comprehensive literature review was carried out to recognize critical elements relevant to the research topic, resulting in the identification of fifteen specific elements that account for 85% of the barriers in SLSC management. The DEMATEL method was used to evaluate the significance and influence levels of these factors. Furthermore, structured in-depth interviews were conducted with ten experts representing sectors that constitute 85% of the SMEs operating in Kayseri Organized Industrial Zone (OIZ), Turkey, including metal products, furniture, plastic packaging, construction materials, textiles and food. The findings reveal that strategies represent the most significant barrier to SLSC management in SMEs. The barriers were analyzed in two dimensions: influencing and influenced factors. The primary influencing factor identified was laws, standards, regulations, and legislation while the most significant influenced factor was found supply and suppliers. The study concludes with findings and actionable recommendations for practitioners and decision-makers.

Keywords: Sustainability, Lean, Supply Chain Management, Barriers, SMEs.

JEL Classification Codes: M00, M10, M11, M19, M20, Q01

Referencing Style: APA 7

INTRODUCTION

With the Covid-19 pandemic, a significant negative deviation between the predicted and actual Human Development Index since 2020 has necessitated the development of a new economic model. Following the "Covid-19: Great Reset Manifesto" proposed at the WEF, the human and planet-oriented "Stakeholder Capitalism" model has emerged as an alternative to the traditional model of modern capitalism. In this context, sustainable development goals were established at the WEF in 2020, and stakeholder capitalism indicators were discussed under four categories: principle of governance, planet, people and prosperity.

According to Linton et al. (2007), sustainability can be approached through macro elements such as the economy and the environment, or it can be related to businesses and their processes. In Sustainable Supply Chain (SSC) management, the sustainability of companies depends on their capacity to manage both cost and quality. Concepts such as "Lean Production, Lean Management, SLSC management and Lean Operations" are gaining prominence. SLSC management, which necessitates collaboration and cooperation among supply chain members particularly with suppliers, requires businesses to undertake various initiatives to enhance their sustainability through joint efforts. However, even when aware of their responsibilities to partners and stakeholders, businesses often encounter various difficulties and barriers during implementation. As of 2020, there are 3.2 million registered SMEs constituting 99.8% of the total businesses in the country. SMEs account for 73.8% of total employment, 64.5% of the total turnover and 56.3% of total exports in Turkey (Division of SME Research and Consultancy Center, 2022).

This research employs a literature review and structured interview technique to identify barriers in SLSC management, elucidating how these barriers structurally influence one using the DEMATEL methodology. The DEMATEL method was created to improve the comprehension of particular issues and to assist in devising practical solutions within a structured framework (Kobryn, A. 2017).

[1] Abdullah Gül University, Kayseri Model Factory, Kocasinan / KAYSERI, ebrutakci@gmail.com

[2] Yaşar University, Department of Business Administration, Bornova / IZMIR, erhan.ada@yasar.edu.tr

[3] Yaşar University, Department of Logistics Management, Bornova / IZMIR, yigit.kazancoglu@yasar.edu.tr
This article is compiled and prepared from Ebru Takcı's doctoral thesis "Barriers in Sustainable Lean Supply Chain Management: Implementation in SMEs.

This research employs the DEMATEL method to systematically solve issues by organizing associated factors into categories of problems and outcomes. This approach facilitates a deeper understanding of casual relationships, organizes factors according to the importance of criteria and investigates the interdependent effects of various relationship types.

This research intends to tackle the subsequent questions:

1. What barriers exist for SLSC management in SMEs in Turkey?
2. In what ways do the barriers faced in SLSC management practices in SMEs in Turkey structurally influence each other?

The findings indicate that *strategies* are of paramount importance among the barriers to SLSC management in SMEs. Furthermore, the barriers in SLSC management have been analyzed from two perspectives: as influencing factors and as influenced factors. It has been determined that *Laws/Standards/Regulations/Legislation* constitute the most significant influencing factor, while the most notable influenced factor is *Supply and Suppliers*.

This research elucidates the impact and interrelationship of the barriers encountered in SLSC applications by employing a structured in-depth interview technique within SMEs.

This study is one of the pioneering investigations conducted in a mixed method framework that reveals the barriers encountered in SLSC applications and examines how these barriers structurally affect one another. This is achieved through structured in-depth interviews and model studies on the barriers in SLSC management in SMEs in Turkey.

The primary limitation of the research is the challenge of comparing the results with other studies due to the scarcity of relevant literature on the subject in Turkey. Another limitation is that SMEs operating in Kayseri may possess limited or no knowledge regarding sustainability and lean transformation.

The research findings, along with recommendations for practitioners and decision-makers, are included in this study.

RELATED LITERATURE REVİEW

Caldera et al. (2019) conducted an evaluation of the facilitators and barriers associated with the successful implementation of sustainable business practices in SMEs, focusing on the issue of SLSC management. Through in-depth interviews with chief executives of SMEs Queensland, Australia, as well as senior managers engaged in sustainability and lean management studies, the research identified several barriers to the adoption of sustainable business practices.

Gupta et al. (2020) researched the barriers to innovation in SSC and proposed strategies to overcome these barriers. Heidary et al. (2020) investigated interaction barriers within SSC management practices. Kazancoglu et al. (2020) presented a conceptual framework for identifying barriers in textile supply chains. Narimissa et al. (2020) explored the drivers and barriers to the implementation and enhancement of SSC. Nazam et al. (2020) conducted a study modeling the primary barriers in knowledge management related to SSC. Furthermore, Nazam et al. (2020) categorized barriers to adopting SSC initiatives to explore pathways to business excellence. Praharsi et al. (2020) discussed the barriers and facilitators affecting SSC development in traditional shipyards in East Java, Indonesia.

Ratna and Kumar (2020) proposed an ISM approach to assess barriers to SSC applications. Sajjad et al. (2020) provided managerial perspectives on the drivers and barriers to SSC implementation, using New Zealand as a case study.

Ada et al. (2021) conducted a systematic literature review of 136 articles to analyze the barriers to circular food supply chains and propose solutions related to Industry 4.0. To understand the concept of the circular economy, applications in food supply chains from 2010 to 2020 were examined using the WOS and Scopus databases, focusing on these barriers. Caldarelli et al. (2021) pragmatically addressed the barriers to blockchain adoption in SSC management within the fashion industry. Chen et al. (2021) explored socio-political sustainability barriers in the Indian banking sector through causality analysis using ISM and MICMAC. Khan et al. (2021) evaluated the barriers and potential solutions for the adoption of social sustainability in multi-layer supply chains. Kouhizadeh et al. (2021) investigated the theoretical barriers to the adoption of blockchain technology and SSC. Kumar et al. (2021) analyzed barriers in SSC for sustainable operations in the context of Industry 4.0 and the circular economy. Additionally, Nair and Thankamony (2021) researched the barriers and applications of social sustainability within supply chains in the energy and manufacturing sectors in Indian and North America.

Palsson and Sandberg (2022) examined the sustainability barriers to sustainable packaging practices in food supply chains in Africa and Sweden. Alayon et al. (2022) investigated the barriers and facilitators for the adoption of sustainability in manufacturing SMEs across seven categories. Guimaraes et al. (2022) researched the barriers to sustainable supply chains in the Brazilian Coffee Industry. According to their survey, the main barriers identified include a lack of government support, high process complexity and communication issues, gaps between parties and insufficient cooperation. Vishwakarma et al. (2022) analyzed the barriers to SSC in the textile sector using a hybrid ISM-MICMAC and DEMATEL approach. The research identified barriers such as communication gaps between stakeholders, factors affecting the performance of the sector, a lack of education and training on sustainability, capacity constraints and insufficient reverse logistics. Hariyani et al. (2022) conducted a literature review on organizational barriers to sustainable production system, while Bhandari et al. (2022) investigated barriers to sustainable resource use in the garment and luxury fashion industry.

Paul et al. (2023) investigated the barriers to SSC management and the strategies to overcome these barriers within the context of the Indian automobile industry, utilizing a literature review and experts' interview. Singh et al. (2023) identified the barriers associated with blockchain technology that hinder supply chain transparency and sustainability in the construction sector, employing the Pythagorean FAHP method. Lahane et al. (2023) assessed and prioritized solutions to address the challenges related to the adoption of Industry 4.0 in sustainable food supply chains. Verma et al. (2023) examined the modeling of 3D printing implementation for sustainable food supply chains, identifying and validating thirteen barriers with input from food printing experts, among which the cost of consumables emerged as a significant barrier. Adams et al. (2023) explored sustainable supply chain barriers in sixteen large food and beverage companies in Australia, highlighting the lack of a governmental regulatory and environmental framework as a major constraint. Kumar Dadsena et al. (2023) analyzed the barriers to supply chain digitization from the perspective of sustainable development goals. Kumar et al. (2024) investigated the barriers to the adoption of Industry 4.0 within the context of sustainable food supply chains, considering a circular economy perspective. Similarly, Rashid et al. (2024) developed a fuzzy multi-criteria model utilizing pareto analysis to prioritize barriers in SSC within the textile industry. Their findings revealed that the major barriers include a lack of commitment from the top management of suppliers and insufficient financial incentives. Singh and Maheswaran (2024) analyzed social barriers to sustainable innovation and digitization in supply chains.

SUSTAINABLE LEAN SUPPLY CHAIN MANAGEMENT

Sustainability is a concept that pertains to various disciplines. The United Nations (UN) Commission on Environment and Development characterizes sustainability as maintaining continuous development by fulfilling societal needs without jeopardizing the requirements of future generations (Brundtland Report, WCED, 1987). As scientific research continues, world leaders at the UN General Assembly in 2015 agreed on a consensus on seventeen global sustainable development goals (70th UN General Assembly, September 28, 2015). Humanity is suffering on our planet due to wars and changing geopolitical dynamics. Crises create challenging living conditions by generating chronic, interacting ambiguities on a global scale. There are now three additional variables contributing to the uncertainties that people have faced throughout history (UNDP, Human Development Report, 2021/2022): dangerous changes in the Anthropocene, the search for social transformations, the excesses of societies divided into opposing groups.

This new uncertainty leads to deficiencies and inequalities in human development. In this regard, according to the UNDP 2021-2022 Human Development Report, the value of the global

Human Development Index is presented in Figure 1. However, research indicates that there has been a negative deviation between the predicted and actual Human Development Index since 2020.

The situation created by the COVID-19 pandemic has necessitated the development of a new economic model. Following the publication of the "COVID-19: The Great Reset" manifesto at the World Economic Forum (WEF) in 2020, a human- and planet-oriented model known as "Stakeholder Capitalism" was proposed as an alternative to the modern capitalism model based on private ownership of manufacturing assets and their use for profit.

Stakeholder Capitalism is a model in which companies, in collaboration with their stakeholders, aim to create long-term value that aligns with societal needs (Schwab, 2021). It is emphasized that companies should benefit not only capitalists but also their stakeholders in order

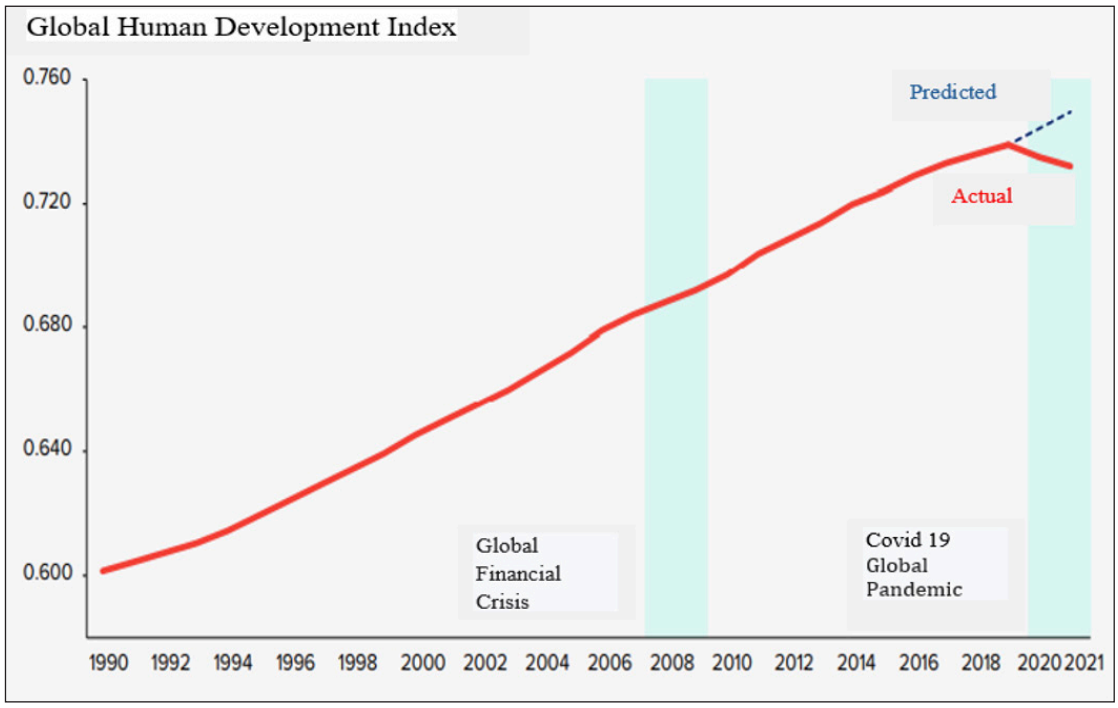

Figure 1. Global Human Development Index

to achieve sustainable development and wealth. In terms of measuring stakeholder capitalism, the WEF (2020) discussed common indicators and consistent reporting frameworks for sustainable development goals and value creation. The WEF categorizes stakeholder capitalism indicators into four main headings: principle of governance, planet, people and prosperity.

In the context of the global economy, characterized by volatile markets, competitive pressures, shortened product lifecycles, stringent quality demands, rapid response requirements, and heightened ecological awareness, the survival of numerous companies increasingly relies on their capacity to consistently enhance quality while lowering costs. Production systems must adapt to constant changes and sustainability requirements. Consequently, there has been considerable interest in the concept of "lean production" and the broader notion of "lean enterprise" in recent years. Womack et al. (1990), in their book, define a "lean system" as one that is free of waste elements. The lean system is an approach that enables manufacturing or service businesses to eliminate waste through employee involvement, organize production resources according to customer demand, and strive for perfection in quality and profitability. Taiichi Ohno (1912-1990), a manager at Toyota Motor Corporation (TMC), identified eight types of waste: defective production, overproduction, waiting, excessive processing, transportation, inventory, unnecessary movement, and unused talent (Begam et al., 2013). Lean operations with low inventory levels are becoming increasingly significant. Numerous organizations have embraced the lean thinking framework to improve performance and strengthen competitive advantage. Based on lean principles, lean manufacturing boosts resource effectiveness, decreases waste and energy expenditure, maximizes both direct and indirect resources, and supports the production of high-quality products at lower expenses. There are five fundamental principles required for the successful implementation of lean systems in businesses: value, value stream, continuous flow, pull system, and perfection (Womack and Jones, 1998).

The concept of lean thinking must be regarded as "sustainable," as it effectively minimizes both the energy required to produce specific products and the waste generated by by-products. Numerous examples illustrate the reduction of human effort, space, and scrap associated with each product through the implementation of lean principles within organizations.

As a result, lean manufacturing and sustainable development are frequently regarded as complementary efforts because of their shared focus on minimizing waste. In contrast to mass production, which emphasizes large batches, lean production focuses on smaller batches and swift adjustments, thereby preventing unnecessary production and excess inventory. The environmental effects of moving from mass production to lean production are considerable. Research in academia

examines the effective and sustainable implementation of lean practices in organizations, underscoring that the main incentive for adopting lean methodologies lies in the economic and environmental benefits linked to sustainability.

Sanders (2012) outlined the benefits of the SLSC system:

1. Financial advantages, including reduced operating and administrative costs, optimized capital investment, and enhanced returns and market valuation.
2. Consumer advantages, such as increased customer satisfaction, expanded market share, enhanced company reputation, and the development of new business opportunities.
3. Operational advantages, including process innovation, improved resource efficiency, reduced processing times and minimized waste.

From a business perspective, an effective SLSC can provide a competitive advantage for supply chain members, shorten lead times, facilitate the implementation of more flexible processes, reduce waste, elevate quality and innovation, strengthen brand image, and enhance reputation. Additionally, improved employee satisfaction resulting from better working conditions may lead to lower turnover rates. From the consumer perspective, enhanced customer satisfaction, increased trust in the brand, and access to healthier, environmentally friendly products are key outcomes. However, barriers encountered during the pursuit of these benefits can significantly affect process performance.

METHODOLOGY

Decision-making is as old as civilization itself. Individuals often intuitively evaluate trade-offs between conflicting criteria to arrive at the optimal alternative in their personal or professional lives. Different MCDM techniques are utilized in research studies. This research utilizes the DEMATEL method, one of the MCDM approaches, to elucidate the interrelationships among barrier criteria and their relative importance. The DEMATEL method was created to determine cause and effect relationships in intricate issues. DEMATEL is a multi-criteria decision-making technique that analyzes structural relationships among criteria, visually represents these relationships in a graphical form, and facilitates the weighting of criteria (Gabus and Fontela, 1972; Kobryń, A., 2017). The DEMATEL method is a calculation system based on pairwise comparison logic, and the steps of the method are outlined below (Ecer, 2020):

Step 1: Pairwise Comparison of Criteria

The degree of influence that the criteria listed in the question table have on each other, based on expert opinions, is determined according to the values presented in Table 1 below.

Step 2: Direct Relationship Matrix X

The element a_{ij} in the matrix represents the degree to which criterion *i* influences criterion *j*.

$$X = \begin{bmatrix} 0 & \cdots & x_{n1} \\ \vdots & \ddots & \vdots \\ x_{n1} & \cdots & 0 \end{bmatrix}_{n \times n}$$

Step 3: Normalized Standard Direct Relationship Matrix $\tilde{x}$

$$\tilde{x} = \frac{X}{maks(maks \ \sum_{j=1}^{n} x_{ij}, \ \sum_{i=1}^{n} x_{ij})}$$

Table 1. Pairwise Comparison Scale

Degree of Importance	Definition	Explanation
0	No Effect	It has no effect on the other factor
1	Low Effect	It has a low effect compared to the other factor
2	Moderate Effect	It has a moderate effect compared to the other factor
3	High Effect	It has a high effect compared to the other factor
4	Very High Effect	It has a very high effect compared to the other factor

Step 4: Total Relationship Matrix T

I : Identity Matrix

$(\tilde{x})$: Standard Direct Relationship Matrix

$T = \tilde{x}.\ (I- X)^{-1}$

Step 5: (D+R) and (D-R) Values

(Identifying the influencing and influenced variables)

Li and Mathiyazhagan (2018) applied the DEMATEL approach to identify effective indicators for the benefits of SSC in the automotive component manufacturing sector. Singh et al. (2021) created a cause-and-effect relationship diagram analyzing barriers to green lean applications in the manufacturing industry, incorporating expert opinions on the impacts of these barriers.

Menon and Ravi (2022) analyzed barriers affecting the implementation of sustainable supply chain management in the electronics industry using the Grey-DEMATEL approach. Zhu et al. (2022) investigated the driving factors for collaborative integration of lean-green manufacturing systems in the context of Industry 4.0, utilizing a fuzzy AHP-DEMATEL-ISM approach.

Ada et al. (2023) examined barriers to the cement industry's transition towards a circular economy with the DEMATEL method. Salman et al. (2024) explored the intersections of lean manufacturing, circular economy, and sustainable development goals through the DEMATEL framework.

This study seeks to recognize barriers in SLSC management by employing structured in-depth interviews within SMEs, as well as to assess the effects and significance levels of the barriers encountered in SLSC applications. This study is among the pioneering investigations employing a mixed-methods approach, elucidating the barriers encountered in practice and how they structurally influence one another, utilizing structured in-depth interviews and model studies on barriers in SLSC management within SMEs. The research population comprises SMEs operating in the Kayseri OIZ and involved senior and middle-level managers through in-depth interviews. A systematic interview with clustering was performed and the information gathered from these interviews was evaluated using the DEMATEL method, a well-known MCDM technique.The proportion of industrial enterprises operating in the Kayseri Organized Industrial Zone (OIZ) is illustrated in Figure 2 (Kayseri Organized Industrial Zone, 2022).

85% of the SMEs operating in the Kayseri OIZ are involved in the metal products, furniture and wooden products, plastic packaging, construction building materials, textile and food sectors. In this research, a structured in-depth interview was conducted with ten experts representing the sector from the sectors that constitute 85% of the SMEs operating in Kayseri OIZ. According to the pareto analysis resulting from interviews and literature review regarding the barriers in SLSC management, 85% of the literature consists of 15 barrier categories:

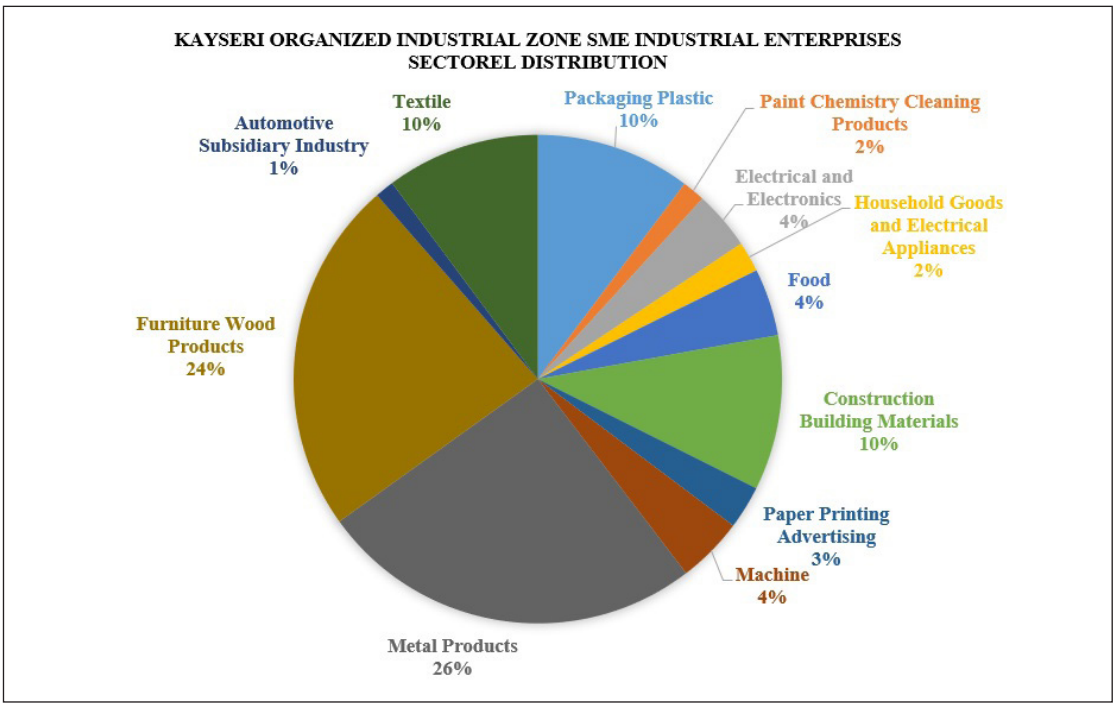

Figure 2. Kayseri Organized Industrial Zone SME Sectoral Distribution

A. (A) Laws / Standards / Regulation / Legislation

B. (B) Institution / Institutional Culture / Change Management

C. (C) Top Management

D. (D) Economics / Finance

E. (E) Supply / Suppliers

F. (F) Customers

G. (G) Training / Expertise

H. (H) Price / Cost

I. (I) Strategies

J. (J) Operational

K. (K) IT / Technology / Innovation

L. (L) Labor

M. (M) Socio-Economic

N. (N) Communication / Media

O. (O) Scientific Information.

Step 1 and 2: Pairwise Comparison of Criteria and *Direct Relationship Matrix X*

A separate direct relationship matrix was created for each participant, and the participants performed pairwise comparisons by progressing from rows to columns, taking into account the comparison scale for the 15 elements. An average direct relationship matrix was obtained from the data collected from the participants. The highest value from the calculations is "41,8". The normalized direct relationship matrix was then calculated based on this value. In the matrix presented in Table 2, the value of 41.8, corresponding to the "C: Top Management" row — which has the highest sum of both the row and column totals — was used.

Step 3: Normalized Standard Direct Relationship Matrix $\tilde{x}$

To standardize X, each value in the X matrix was divided by the largest total value (41.8), thereby generating the normalized standard relationship matrix presented in Table 3.

Step 4: Total Relationship Matrix T

The total relationship matrix presented in Table 4.

Step 5: (D+R) and (D-R) Values

The D + R values, which represent the level of importance of the barriers in SLSC management, are presented in Table 5.

The D - R values, which represent the degree of impact of the barriers in SLSC management, are presented in Table 6.

The impact diagram, which illustrates the order of importance and the relationships among barrier criteria in SLSC management, is presented in Figure 3.

Table 2. Direct Relationship Matrix

SLSC MANAGEMENT BARRIERS		A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	TOTAL
Laws / Standards / Regulation / Legislation	A	0	3,3	3,3	3,1	2,7	2,7	2,3	2,9	3,1	2,9	2,4	2,6	1,9	2,5	2,4	38,1
Institution / Institutional Culture / Change Management	B	1,4	0	2,8	2,3	2,8	2,9	3,1	2,6	3,3	3	2,6	2,6	2,4	2,7	2,2	36,7
Top Management	C	1,4	3,9	0	3,2	2,8	2,9	3	3,3	3,9	3	3,1	3,1	2,6	3,4	2,2	**41,8**
Economics / Finance	D	1,6	2,7	3,2	0	3	3,1	2,3	3,4	3,4	3,1	3,1	2,8	2,9	2,4	2,1	39,1
Supply / Suppliers	E	1,9	2,1	2,2	2,6	0	2	1,2	3,5	2,6	2,9	1,6	2	1,3	1,3	1,2	28,4
Customers	F	1,5	2,9	2,3	3,3	1,9	0	1,9	3,4	3,4	2,7	2,3	2	2,2	2,7	1,6	34,1
Training / Expertise	G	1,9	2,7	2,4	2,4	2,1	2,6	0	2,6	2,9	2,9	3,1	2,9	2,8	2,5	3,4	37,2
Price / Cost	H	1,4	2,4	2,9	3,7	3,4	3,6	2,3	0	3,3	2,8	2,9	2,7	2,7	2,1	1,7	37,9
Strategies	I	2,3	3,3	3,2	3,1	2,8	3,1	2,7	3,4	0	3,1	3	2,5	2,6	2,7	2,5	40,3
Operational	J	2,2	2,6	2,2	2,5	2,6	2,6	2,5	3,3	2,4	0	2,7	2,9	2,1	1,7	1,7	34
IT / Technology / Innovation	K	1,4	2,6	2,6	2,7	1,9	2,4	2,6	2,9	2,9	3,1	0	2,4	1,8	3,1	3,3	35,7
Labor	L	1,7	2,4	2,3	2,8	1,8	2,1	2,2	3,2	2,6	3,1	1,9	0	2,4	1,6	1,2	31,3
Socio-Economic	M	1,3	2,2	1,8	2,3	1,9	2,3	2,4	2,5	2,4	2	2,2	2,7	0	2,1	1,6	29,7
Communication / Media	N	1,4	2,1	2,3	2,3	2,0	3,2	1,8	2,1	2,4	1,4	1,9	1,9	1,7	0	1,5	28
Scientific Information	O	2,3	2,5	2,4	2,1	2,1	2	2,9	2,3	2,4	2,2	2,9	2	1,6	1,8	0	31,5

Table 3. *Normalized Standard Direct Relationship Matrix*

SLSC MANAGEMENT BARRIERS		A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	TOTAL
Laws / Standards / Regulation / Legislation	A	-	0,08	0,08	0,07	0,06	0,06	0,06	0,07	0,07	0,07	0,06	0,06	0,05	0,06	0,06	0,91
Institution / Institutional Culture / Change Management	B	0,03	-	0,07	0,06	0,07	0,07	0,07	0,06	0,08	0,07	0,06	0,06	0,06	0,06	0,05	0,88
Top Management	C	0,03	0,09	-	0,08	0,07	0,07	0,07	0,08	0,09	0,07	0,07	0,07	0,06	0,08	0,05	1,00
Economics / Finance	D	0,04	0,06	0,08	-	0,07	0,07	0,06	0,08	0,08	0,07	0,07	0,07	0,07	0,06	0,05	0,94
Supply / Suppliers	E	0,05	0,05	0,05	0,06	-	0,05	0,03	0,08	0,06	0,07	0,04	0,05	0,03	0,03	0,03	0,68
Customers	F	0,04	0,07	0,06	0,08	0,05	-	0,05	0,08	0,08	0,06	0,06	0,05	0,05	0,06	0,04	0,82
Training / Expertise	G	0,05	0,06	0,06	0,06	0,05	0,06	-	0,06	0,07	0,07	0,07	0,07	0,07	0,06	0,08	0,89
Price / Cost	H	0,03	0,06	0,07	0,09	0,08	0,09	0,06	-	0,08	0,07	0,07	0,06	0,06	0,05	0,04	0,91
Strategies	I	0,06	0,08	0,08	0,07	0,07	0,07	0,06	0,08	-	0,07	0,07	0,06	0,06	0,06	0,06	0,96
Operational	J	0,05	0,06	0,05	0,06	0,06	0,06	0,06	0,08	0,06	-	0,06	0,07	0,05	0,04	0,04	0,81
IT / Technology / Innovation	K	0,03	0,06	0,06	0,06	0,05	0,06	0,06	0,07	0,07	0,07	-	0,06	0,04	0,07	0,08	0,85
Labor	L	0,04	0,06	0,06	0,07	0,04	0,05	0,05	0,08	0,06	0,07	0,05	-	0,06	0,04	0,03	0,75
Socio-Economic	M	0,03	0,05	0,04	0,06	0,05	0,06	0,06	0,06	0,06	0,05	0,05	0,06	-	0,05	0,04	0,71
Communication / Media	N	0,03	0,05	0,06	0,06	0,05	0,08	0,04	0,05	0,06	0,03	0,05	0,05	0,04	-	0,04	0,67
Scientific Information	O	0,06	0,06	0,06	0,05	0,05	0,05	0,07	0,06	0,06	0,05	0,07	0,05	0,04	0,04		0,75

Table 4. *Total Relationship Matrix*

SLSC MANAGEMENT BARRIERS		A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	D
Laws / Standards / Regulation / Legislation	A	0.22	0.41	0.40	0.42	0.37	0.40	0.35	0.44	0.44	0.41	0.38	0.38	0.33	0.35	0.31	5.67
Institution / Institutional Culture / Change Management	B	0.24	0.32	0.37	0.38	0.36	0.39	0.36	0.42	0.43	0.40	0.37	0.36	0.33	0.34	0.30	5.43
Top Management	C	0.27	0.45	0.35	0.45	0.40	0.44	0.39	0.48	0.49	0.44	0.42	0.41	0.37	0.40	0.33	6.15
Economics / Finance	D	0.26	0.41	0.40	0.35	0.38	0.42	0.36	0.46	0.45	0.42	0.40	0.39	0.36	0.36	0.31	5.78
Supply / Suppliers	E	0.21	0.31	0.30	0.32	0.24	0.31	0.26	0.36	0.34	0.33	0.28	0.29	0.25	0.25	0.22	4.32
Customers	F	0.23	0.37	0.34	0.39	0.32	0.31	0.31	0.41	0.41	0.37	0.34	0.33	0.31	0.33	0.27	5.11
Training / Expertise	G	0.25	0.39	0.37	0.39	0.35	0.39	0.29	0.42	0.42	0.40	0.38	0.37	0.34	0.34	0.33	5.49
Price / Cost	H	0.25	0.39	0.39	0.43	0.38	0.42	0.35	0.37	0.44	0.41	0.39	0.38	0.34	0.34	0.30	5.62
Strategies	I	0.28	0.43	0.41	0.43	0.39	0.43	0.38	0.47	0.39	0.43	0.41	0.39	0.36	0.37	0.33	5.96
Operational	J	0.24	0.36	0.34	0.37	0.33	0.36	0.33	0.41	0.38	0.31	0.35	0.35	0.30	0.30	0.27	5.08
IT / Technology / Innovation	K	0.23	0.38	0.36	0.38	0.33	0.37	0.34	0.41	0.41	0.39	0.30	0.35	0.31	0.35	0.32	5.30
Labor	L	0.22	0.34	0.32	0.35	0.30	0.33	0.30	0.38	0.37	0.36	0.31	0.26	0.29	0.28	0.24	4.72
Socio-Economic	M	0.20	0.31	0.29	0.32	0.28	0.32	0.29	0.35	0.34	0.32	0.30	0.31	0.22	0.28	0.24	4.45
Communication / Media	N	0.19	0.30	0.29	0.31	0.27	0.32	0.26	0.33	0.33	0.29	0.28	0.28	0.25	0.22	0.23	4.22
Scientific Information	O	0.23	0.34	0.32	0.34	0.30	0.33	0.32	0.36	0.36	0.34	0.34	0.31	0.27	0.29	0.22	4.74
	R	3.58	5.57	5.33	5.70	5.07	5.59	4.95	6.13	6.06	5.68	5.32	5.23	4.68	4.87	4.28	

Table 5. *D+R*

SLSC MANAGEMENT BARRIERS		Di	Rj	Di+Rj	Level of Relationship
Laws / Standards / Regulation / Legislation	A	5,678	3,581	9,259	12
Institution / Institutional Culture / Change Management	B	5,438	5,578	11,016	5
Top Management	C	6,158	5,335	11,493	4
Economics / Finance	D	5,786	5,709	11,495	3
Supply / Suppliers	E	4,326	5,071	9,397	11
Customers	F	5,116	5,596	10,711	7
Training / Expertise	G	5,494	4,954	10,447	9
Price / Cost	H	5,620	6,132	11,751	2
Strategies	I	5,961	6,063	12,024	1
Operational	J	5,081	5,682	10,763	6
IT / Technology / Innovation	K	5,302	5,326	10,628	8
Labor	L	4,723	5,230	9,952	10
Socio-Economic	M	4,450	4,687	9,137	13
Communication / Media	N	4,227	4,877	9,104	14
Scientific Information	O	4,744	4,282	9,025	15

Table 6. *D-R*

SLSC MANAGEMENT BARRIERS		Di	Rj	Di - Rj	Impact Group
Laws / Standards / Regulation / Legislation	A	5,678	3,581	2,096	Influencing
Institution / Institutional Culture / Change Management	B	5,438	5,578	-0,139	Influenced
Top Management	C	6,158	5,335	0,823	Influencing
Economics / Finance	D	5,786	5,709	0,077	Influencing
Supply / Suppliers	E	4,326	5,071	-0,745	Influenced
Customers	F	5,116	5,596	-0,480	Influenced
Training / Expertise	G	5,494	4,954	0,540	Influencing
Price / Cost	H	5,620	6,132	-0,512	Influenced
Strategies	I	5,961	6,063	-0,102	Influenced
Operational	J	5,081	5,682	-0,601	Influenced
IT / Technology / Innovation	K	5,302	5,326	-0,023	Influenced
Labor	L	4,723	5,230	-0,507	Influenced
Socio-Economic	M	4,450	4,687	-0,237	Influenced
Communication / Media	N	4,227	4,877	-0,650	Influenced
Scientific Information	O	4,744	4,282	0,461	Influencing

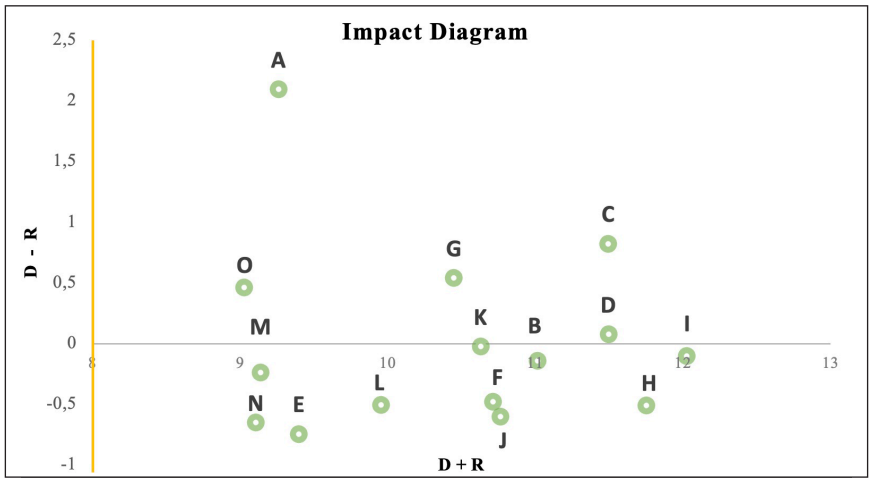

Figure 3. Impact Diagram

CONCLUSION AND SUGGESTIONS

The DEMATEL method was employed in this research to determine the importance and priority order of fifteen elements identified as barriers in SLSC management, as well as to reveal the levels of influence among these elements.

The barriers in SLSC management, ranked according to their degree of importance, are as follows, following the stages and analyses of the DEMATEL method:

1. Strategies (I)
2. Price / Cost (H)
3. Economics / Finance (D)
4. Senior Management (C)
5. Institution / Corporate Culture / Change Management (B)
6. Operational (J)
7. Customers (F)
8. IT / Technology / Innovation (K)
9. Education / Expertise (G)
10. Labor Force (L)
11. Supply / Suppliers (E)
12. Laws / Standards / Regulation / Legislation (A)
13. Socio-economic (M)
14. Communication / Media (N)
15. Scientific Knowledge (O)

The barrier factors in SLSC management, ranked according to their levels of impact, are as follows: The order of "influencing" barriers in SMEs, from the most effective to the least effective, is as follows:

1. Laws / Standards / Regulation / Legislation (A)
2. Senior Management (C)
3. Education / Expertise (G)
4. Scientific Knowledge (O)
5. Economics / Finance (D)

Among the barrier criteria in SLSC management within SMEs, the order of barriers that are 'influenced' by other criteria is as follows:

1. Supply / Suppliers (E)
2. Communication / Media (N)
3. Operational (J)
4. Price / Cost (H)
5. Labor Force (L)
6. Customers (F)
7. Socio-economic (M)
8. Institution / Corporate Culture / Change Management
9. Strategies
10. IT / Technology / Innovation

The findings indicate that strategies are of paramount importance among the barriers to SLSC management in SMEs. The barrier factors in SLSC management have been examined from two perspectives: influencing and influenced. It has been determined that *Laws/Standards/Regulations/Legislation* is the most significant influencing factor, while *Supply/Suppliers* is identified as the most critical influenced factor. It is posited that the barriers to SLSC management identified in this study, along with the importance levels of these barriers, can serve as a guide for SMEs operating in Turkey. Accordingly, policymakers and practitioners should concentrate on these barrier criteria and take proactive measures in SLSC management. The following recommendations are proposed for policymakers:

1. Sustainability strategies and policies should be established prior to the implementation of SLSC initiatives in SMEs. Key performance indicators aligned with these strategies and policies should be determined, and sustainability efforts should be monitored using these indicators.
2. The lean and sustainability maturity levels of SMEs should be assessed. A development roadmap should be prepared based on these maturity levels, and the implementation of actions outlined in the roadmap should be mandatory. Studies on pricing should be conducted in conjunction with lean practices that enable SMEs to reduce costs while aligning with their business strategies. Lean initiatives that contribute to the 4Ps should be integrated throughout the supply chain.
3. Economic and financial support should be

provided to SMEs for the implementation of their sustainability strategies. In this regard, enterprises should be encouraged to focus on SLSC initiatives.

4. Scientific research on SLSC should be enhanced, and researchers should be encouraged to engage with this subject.

5. The operational lean transformation of SMEs should be encouraged and supported, with operational processes designed according to the principles of the 4Ps in sustainability.

6. Processes within SMEs should be designed innovatively with a lean perspective, utilizing technology to reduce operational risks while effectively and efficiently using resources and labor. Existing workflows and manual process steps should be identified, and digital roadmaps should be developed.

7. The media should create content that emphasizes the importance of sustainability and lean transformation, communicate best practices to the broader society, and prioritize SLSC management as a critical issue.

The following recommendations are proposed for practitioners:

1. Stakeholders, such as professional chambers, should provide guidance to the senior management of SMEs on sustainability and offer information and training support regarding legal frameworks, legislation, and other relevant areas during the implementation of strategies.

2. Organizational development strategies should be formulated for corporate culture and change management in SMEs engaged in SLSC management. Training and consultancy services should be sought in this regard, with financial incentives provided for such services.

3. In the management of SLSC within SMEs, significant emphasis should be placed on laws, standards, regulations, and legislation.

4. Practical training on sustainability and lean practices should be disseminated to the workforce throughout the supply chain. Experts in sustainability and lean methodologies should be trained, and their numbers should be increased.

5. Customers should actively demand SLSC applications from their suppliers, and they should organize supplier development programs focused on sustainability and lean transformation.

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