Chapter 4

INDUSTRY 4.0 ADOPTION BARRIERS

4.1 Introduction

The integration of I4.0 into supply chains necessitates a comprehensive approach involving multiple stakeholders, including suppliers, manufacturers, and distributors. To overcome challenges related to digital literacy, trust, data privacy, security, standardization, and cost, blockchain technology can play a pivotal role in reshaping supply chains and enhancing efficiency, transparency, trust, and traceability (Vazquez et al., 2024). A holistic perspective is essential for organizations looking to adopt I4.0 throughout their supply chain network, as it should encompass various obstacles related to organizational adoption. These barriers encompass factors such as perceived benefits, readiness, collaboration and trust, regulatory and legal considerations, as well as cost implications. A case of blockchain technology is considered for incorporation. Blockchain technology adoption in supply chain strategy hinges on addressing these barriers (Shahzad et al., 2024). The true value of blockchain technology in the supply chain lies in its capacity to enhance traceability, accountability, and transparency, all while alleviating administrative burdens for the parties involved in the supply chain (Niu et al., 2021). Nandi et al. (2021) suggest that the COVID-19 pandemic presents an opportunity to reevaluate and redesign supply chains to be more resilient, transparent, and sustainable. The implementation of blockchain technology can enable supply chain participants to engage in cooperative efforts aimed at establishing sustainable supply chains. This approach requires collaboration and synchronization among multiple tiers and diverse participants, encompassing individuals, organizations, supply chains, governments, and communities (Xia et al., 2023). The evaluation of the influence of blockchain technology on the performance of sustainable supply chains can be conducted using various indicators, including transparency, efficiency, trust, implementation of smart contracts, and data privacy and security (Pattanayak et al., 2024; Yousefi et al., 2022).

Most BT applications are conceptual representations with limited empirical evidence for implementation. Furthermore, little research has been done on the challenges of BT adoption considering barriers under the roof of economic, legal, behavioral, and technical for global supply chains. Hence, this research study provides a systematic examination of the integration of blockchain technology within supply chain networks and explores the potential challenges that may arise during its implementation.

The study has the following objectives:

I. To identify BT adoption barriers under the economic, legal, behavioral, and technological categories for the global supply chain.

II. To explore the correlation among BT adoption barriers under the economic, legal, behavioral, and technological categories for the global supply chain.

III. To suggest mitigation strategies and priorities.

4.2 Methodology

Grey systems are employed to model systems that lack comprehensive information, clear-cut instructions, or well-defined operational procedures. They are particularly suited for situations where there is a degree of uncertainty, incomplete data, or limited information available. In the context of grey systems, terms like "grey relations," "grey elements," and "grey numbers" are used to describe and analyze the aspects of the problem being investigated. The term "grey" is typically associated with phenomena or elements that possess uncertain or ambiguous characteristics due to the presence of incomplete or limited information. Grey numbers are a relatively new technique, first proposed by Deng Julong in 1982. Unlike the DEMATEL, which uses a single number to represent the expert opinion, the grey DEMATEL uses grey number intervals, allowing to building of a more flexible and comprehensive decision-making model to determine the outcome of your decision, which could be made more realistic. Just as the fuzzy method uses quantifiers to express the expert's opinion based on a scale, Grey's method uses two quantifiers consisting of a series of integers and decimal numbers to express the expert's opinion. Based on the opinion a direct impact matrix is constructed through the logical relationships between the various barriers in the system The impact of each barrier was found out, and classified into cause and effect barriers. Grey numbers allow models to quantify the combined effects of different influencing barriers while clarifying analysis, avoiding ambiguity, and better approximating reality.

The grey system is used in combination with the DEMATEL approach to identify the causal relations and correlation power of BT adoption barriers related to the supply chain. For a detailed examination of the factors that influence the barriers to the adoption of BT in the supply chain grey-DEMATEL is successfully applied. Figure 6 depicts a comprehensive framework that facilitates the analysis of the cause-and-effect relationship about the barriers hindering the adoption of BT in supply chains. This methodology offers notable benefits when confronted with insufficient or restricted data, making it highly suitable for analyzing the barriers to blockchain technology adoption. The identification of sixteen distinct barriers was accomplished by conducting a comprehensive literature review and administering a questionnaire to professionals in the industry, as well as academics and research scholars.

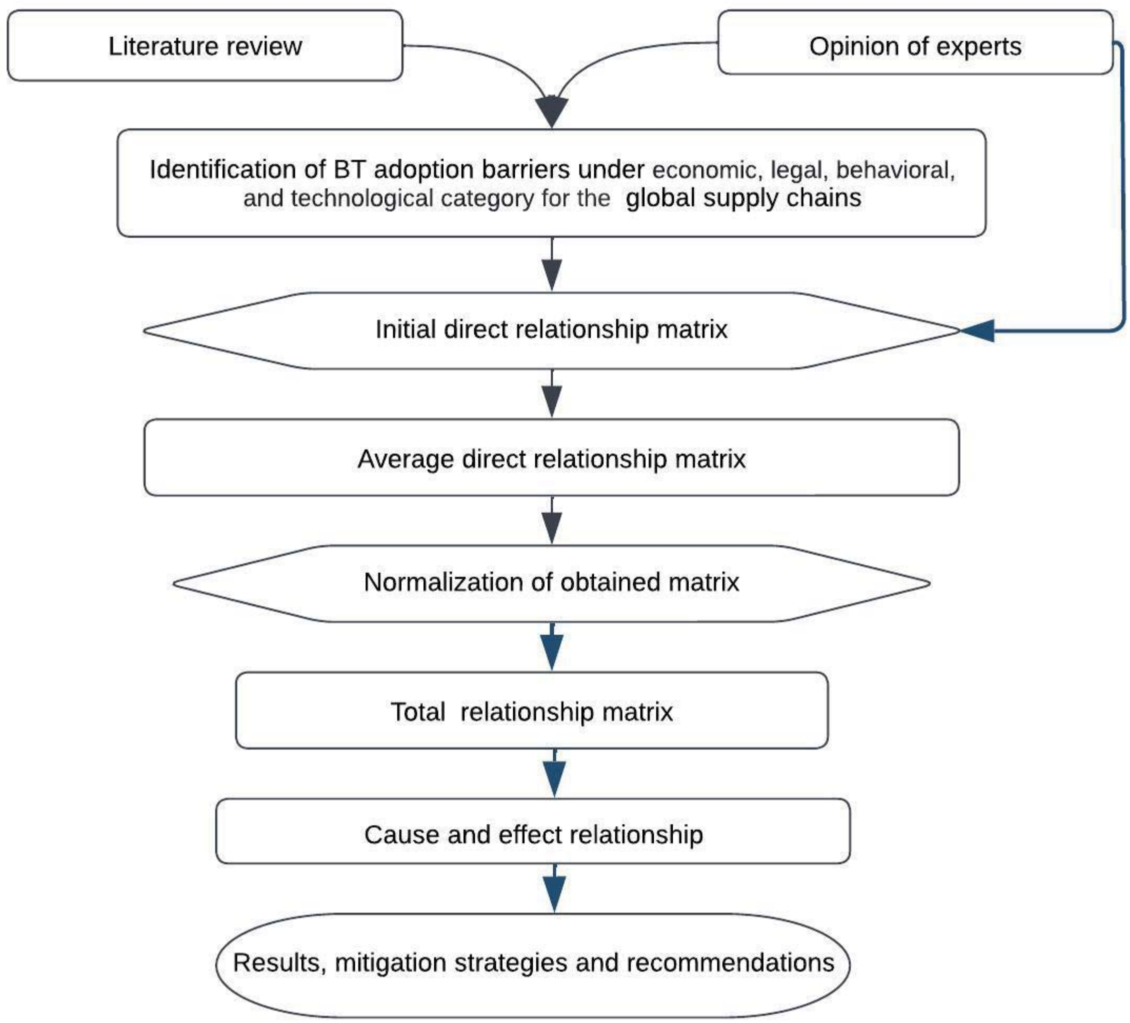

Figure 6: Proposed framework.

To obtain the initial direct relationship the Delphi technique was utilized in several steps. First, the factors are identified based on a literature review, and further, these identified factors are presented separately by 6 experts. 3 experts are from academic and research backgrounds with 4 years of familiarity with BT in the context of global supply chains. The remaining 3 experts are from industry backgrounds with an average experience of 5 years relevant to BT in the supply chain domain. The details of the experts are delineated in Table 2.

Table 2: Specification of experts

Respondents	Number of questionnaires sent for screening	Average experience (in years)	For interrelations	Average experience relevant to BT in the supply chain domain (in years)
Academician	95	4.0	2	4
Research Scholars	124	1.5	1	4
Industry experts	25	5.0	3	5

Through multiple rounds, until a consensus is reached among experts, the experts identified the final 16 adoption barriers along with their interrelations. These 16 BT adoption barriers belong to the category of economic, behavioral, legal, and technical categories (Table 3).

Table 3: BT adoption barriers for the global supply chain

Groups	**Sl.no**	**Barriers**	**Description**	**References**
Economical barriers	1	Increased costs	Extra expenses for infrastructure, manpower, and training.	(Zhang and Song, 2022; Govindan et al., 2023)
	2	Extra audits and recertification	Need for ground audits and recertification to ensure real-world compliance	(Zhang and Song, 2022; Saberi et al., 2019)
	3	Limited financial capability	Resources and accessibility are constrained, resulting in restricted strengths and capabilities.	(Ul Islam et al., 2022; Govindan et al., 2023)
	4	Market competition and uncertainty	Rapidly changing market conditions hinder the BT adoption and new practices.	(Zkik et al., 2022; Govindan et

				al., 2023; Saberi et al., 2019)
Legal barriers	5	Non-visibility in the taxation system	Many companies frequently exhibit hesitancy in embracing BT as a result of apprehensions surrounding the lack of clearly defined and transparent taxation systems pertaining to transactions and financial operations.	(Almutairi et al., 2022; Karakas et al., 2021)
	6	Lack of policy for Blockchain Technology	The lack of clear policy especially at the government level hinders BT adoption in the supply chain.	(Zkik et al., 2022; Karakas et al., 2021; Saberi et al., 2019)
	7	Regulation uncertainty	The regulation uncertainty of different countries hinders the unified adoption policy for the global supply chain network.	(Callinan, 2022; Karakas et al., 2021; Saberi et al., 2019)
Behavioral barriers	8	Lack of expertise	The lack of expertise to adapt to new systems.	(Callinan, 2022; Maciel et al., 2021; Karakas et al., 2021)
	9	Deficiency of approach	A deficiency of approach leads to the creation of inefficient plans for the transfer from one system to another.	(Ul Islam et al., 2022; Saberi et al., 2019)

	10	Trust issues	The implementation of a distributed platform and shared database is hindered due to a lack of trust among supply chain stakeholders.	(Zhang and Song, 2022; Maciel et al., 2021)
	11	Absence of adaptability	Adoption to a new system often brings challenges. The absence of necessary adaptability hinders the implementation of new practices in the supply chain network.	(Ul Islam et al. 2022; Maciel et al., 2021; Saberi et al., 2019)
Technical barriers	12	Technical complexity	The technical complexity of the new system often leads to the adoption challenges in the existing systems.	(Zkik et al., 2022; Govindan et al., 2023; Mathivathanan et al., 2021)
	13	Integrational challenge	New systems often lead to integrational challenges to the existing systems.	(Callinan, 2022; Govindan et al., 2023; Mathivathanan et al., 2021)
	14	Interoperability issue	Interoperability refers to the concepts of interoperability across different systems and stakeholders throughout the network.	(Zhang and Song, 2022; Karakas et al., 2021; Govindan et al., 2023)
	15	Scalability issue	Scalability may be hindered by the lack of IT infrastructure and	(Callinan, 2022; Karakas et al., 2021;

			technology, both at the software and hardware levels.	Mathivathanan et al., 2021)
	16	Data privacy issue	BT is predicated on the dissemination of transaction data among participants in the supply chain, thereby potentially influencing the confidentiality and privacy of the entities engaged in the process.	(Zkik et al., 2022; Govindan et al., 2023; Mathivathanan et al., 2021)

Step 1. Identifying the barriers and questionnaire-making

As the MCDM methodology is expert opinion-based, it identifies barriers affecting the integration of blockchain technology into supply chains. A set of questions related to all barriers through a literature review and a group of experts is obtained.

Step 2: Establishment of Initial Matrix

A group of industry experts (Table 2) was invited to ask questions about the latest developments in blockchain technology. They received a questionnaire and were asked to fill it out. Based on those evaluations, an initial matrix was constructed using the scale shown in Table 4. Given the different experiences of experts, there are different understandings of the barriers to implementing BT in supply chains. Therefore, the weight given to each expert is different.

Table 4: Linguistic scale

Linguistic Assessment	Weight	Grey Scale
No Impact (N)	0	[0.0,0.1]
Very low Impact (VL)	1	[0.1,0.3]
Low Impact (L)	3	[0.2,0.5]
Medium Impact (M)	5	[0.4,0.7]
High Impact (H)	7	[0.6, 0.9]

Very high Impact (VH)	9	[0.9, 1.0]

Step 3. Calculating the average relational matrix

Consider N as the number of Barriers in BT implementation and K as the number of experts who responded to the questionnaire. y participant is assigned the responsibility of assessing the specific influence of barrier 'i' on barrier 'j' using a numerical scale that spans from 0 to 5. The scale provided herein serves as a metric for quantifying the level of impact exhibited by the identified facilitators, denoted by integers ranging from 0 to 5. No impact is indicated by a score of 0, whereas those of 1, 2, 3, 4, and 5 indicate varying degrees of impact, from very low to very high. As a result, it is necessary to combine 'k' initial relational matrices into a unified matrix in order to integrate the comprehensive evaluation of the interplay between barriers.

$$\emptyset G_{ij}^{l} = \left(\emptyset\_G_{ij}^{l}, \overline{\emptyset}G_{ij}^{l}\right) \quad (1)$$

Where $1 \leq l \leq k;\ 1 \leq I \leq n; 1 \leq j \leq n$.

Grey relational matrix on average $[\emptyset G_{ij}^{l}]$ is computed using k grey relation matrices,

$$[\emptyset G_{ij}^{l}];=1-k\ as, \quad (2)$$

$$\emptyset \dot{G}_{ij}^{l} = \left(\frac{\sum_l \emptyset G_{ij}^{l}}{k}, \frac{\sum_l \overline{\emptyset} G_{ij}^{l}}{k}\right) \quad (3)$$

Step 4: Computing crisp matrices for average grey matrices

Calculating the upper and lower bound of the Normalized matrix.

$$\emptyset\_\dot{G}_{ij} = \left(\emptyset\_\breve{G}_{ij} - {}^{min}{}_{j}\emptyset\_\breve{G}_{ij}^{l}\right)/\Delta_{min}^{max} \quad (4)$$

Where $[\otimes\dot{G}_{ij}]$ is the grey number's normalized lower limit value $[\otimes\breve{G}_{ij}]$.

$$\overline{\emptyset}\dot{G}_{ij} = \left(\emptyset\breve{G}_{ij} - {}^{min}{}_{j}\overline{\emptyset}\breve{G}_{ij}^{l}\right)/\Delta_{min}^{max} \quad (5)$$

where $[\overline{\otimes}\dot{G}_{ij}]$ represents the normalized upper limit value of the grey number $[\overline{\otimes}\breve{G}_{ij}]$.

$$\Delta_{min}^{max} = {}^{max}{}_{j}\overline{\emptyset}\breve{G}_{ij} - {}^{min}{}_{j}\emptyset\dot{G}_{ij}^{l} \quad (6)$$

The Normalized crisp value is calculated

$$X_{ij} = \left(\frac{\left(\emptyset\dot{G}_{ij}(1-\emptyset\dot{G}_{ij}) + (\overline{\emptyset}\dot{G}_{ij} \times \overline{\emptyset}\dot{G}_{ij})\right)}{(1-\emptyset\dot{G}_{ij} + \overline{\emptyset}\dot{G}_{ij})}\right) \quad (7)$$

The final crisp value calculated is shown in Table 3

$$X_{ij}^{*} = \left(min\emptyset\dot{G}_{ij} + \left(X_{ij} \times \Delta_{min}^{max}\right)\right) \quad (8)$$

And

$$X = [X_{ij}^{*}] \quad (9)$$

Table 5: The final crisp value matrix

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	0	0.846	0.289	0.5	0.745	0.27	0.118	0.36	0.36	0.9	0.269	0.415	0.119	0.415	0.64	0.367
2	0.178	0	0.436	0.407	0.273	0.646	0.407	0.407	0.64	0.5	0.363	0.367	0.27	0.12	0.36	0.415
3	0.509	0.269	0	0.118	0.509	0.27	0.267	0.9	0.267	0.733	0.503	0.745	0.505	0.604	0.733	0.509
4	0.273	0.363	0.533	0	0.509	0.505	0.5	0.5	0.733	0.5	0.119	0.12	0.119	0.12	0.267	0.273
5	0.745	0.269	0.289	0.5	0	0.27	0.267	0.733	0.9	0.267	0.269	0.178	0.119	0.273	0.174	0.208
6	0.509	0.503	0.533	0.9	0.509	0	0.5	0.267	0.9	0.407	0.503	0.208	0.176	0.273	0.204	0.178
7	0.273	0.503	0.289	0.5	0.745	0.505	0	0.5	0.9	0.733	0.503	0.745	0.505	0.509	0.267	0.745
8	0.604	0.597	0.533	0.81	0.651	0.74	0.9	0	0.5	0.5	0.269	0.745	0.74	0.745	0.733	0.509
9	0.745	0.269	0.533	0.267	0.273	0.646	0.733	0.844	0	0.733	0.503	0.12	0.815	0.273	0.267	0.178
10	0.509	0.503	0.125	0.733	0.509	0.27	0.118	0.81	0.5	0	0.846	0.367	0.74	0.745	0.5	0.509
11	0.12	0.503	0.436	0.267	0.367	0.505	0.267	0.5	0.733	0.5	0	0.273	0.27	0.509	0.9	0.273

12	0.509	0.269	0.289	0.5	0.745	0.815	0.733	0.733	0.81	0.593	0.738	0	0.505	0.273	0.733	0.367
13	0.273	0.738	0.533	0.5	0.509	0.505	0.593	0.267	0.5	0.9	0.503	0.509	0	0.208	0.267	0.509
14	0.273	0.269	0.289	0.844	0.273	0.27	0.5	0.5	0.36	0.844	0.41	0.2	0.505	0	0.5	0.273
15	0.651	0.644	0.533	0.267	0.745	0.646	0.733	0.733	0.267	0.733	0.738	0.12	0.411	0.273	0	0.509
16	0.745	0.738	0.436	0.5	0.651	0.74	0.81	0.593	0.118	0.81	0.813	0.208	0.74	0.12	0.593	0

Step 5: The normalized direct-relation matrix was obtained.

Table 6 displays the normalized direct relation matrix that was created using the formula below. The value of the matrix ranges between 0 and 1.

$$L = \frac{1}{\max\limits_{1 \le i \le n} \sum_{j=1}^{n} X_{ij}^{*}} \quad (10)$$

$$N = L \times X \quad (11)$$

Where;

N = Normalized direct relation matrix

L = The normalization factor,

X = The initial crisp relationship matrix

Table 6: The normalized direct relation matrix

	N=L*A															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	0	0.088	0.03	0.052	0.078	0.028	0.012	0.038	0.038	0.094	0.028	0.043	0.012	0.043	0.067	0.038
2	0.019	0	0.045	0.042	0.028	0.067	0.042	0.042	0.067	0.052	0.038	0.038	0.028	0.013	0.038	0.043

3	0.053	0.028	0	0.012	0.053	0.028	0.028	0.094	0.028	0.077	0.053	0.078	0.053	0.063	0.077	0.053
4	0.028	0.038	0.056	0	0.053	0.053	0.052	0.052	0.077	0.052	0.012	0.013	0.012	0.013	0.028	0.028
5	0.078	0.028	0.03	0.052	0	0.028	0.028	0.077	0.094	0.028	0.028	0.019	0.012	0.028	0.018	0.022
6	0.053	0.053	0.056	0.094	0.053	0	0.052	0.028	0.094	0.042	0.053	0.022	0.018	0.028	0.021	0.019
7	0.028	0.053	0.03	0.052	0.078	0.053	0	0.052	0.094	0.077	0.053	0.078	0.053	0.053	0.028	0.078
8	0.063	0.062	0.056	0.085	0.068	0.077	0.094	0	0.052	0.052	0.028	0.078	0.077	0.078	0.077	0.053
9	0.078	0.028	0.056	0.028	0.028	0.067	0.077	0.088	0	0.077	0.053	0.013	0.085	0.028	0.028	0.019
10	0.053	0.053	0.013	0.077	0.053	0.028	0.012	0.085	0.052	0	0.088	0.038	0.077	0.078	0.052	0.053
11	0.013	0.053	0.045	0.028	0.038	0.053	0.028	0.052	0.077	0.052	0	0.028	0.028	0.053	0.094	0.028
12	0.053	0.028	0.03	0.052	0.078	0.085	0.077	0.077	0.085	0.062	0.077	0	0.053	0.028	0.077	0.038
13	0.028	0.077	0.056	0.052	0.053	0.053	0.062	0.028	0.052	0.094	0.053	0.053	0	0.022	0.028	0.053
14	0.028	0.028	0.03	0.088	0.028	0.028	0.052	0.052	0.038	0.088	0.043	0.021	0.053	0	0.052	0.028
15	0.068	0.067	0.056	0.028	0.078	0.067	0.077	0.077	0.028	0.077	0.077	0.013	0.043	0.028	0	0.053
16	0.078	0.077	0.045	0.052	0.068	0.077	0.085	0.062	0.012	0.085	0.085	0.022	0.077	0.013	0.062	0

Step 6: The total relational matrix "S" was calculated using the below mentioned formula is shown in Table 7

$$S = N(I - N)^{-1} \tag{12}$$

I= Identity matrix

Table 7: The Total Relational Matrix

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	0.128	0.214	0.139	0.189	0.216	0.164	0.145	0.195	0.191	0.255	0.16	0.137	0.133	0.144	0.19	0.143
2	0.135	0.119	0.145	0.166	0.158	0.189	0.163	0.183	0.204	0.203	0.157	0.125	0.138	0.106	0.151	0.138
3	0.202	0.185	0.13	0.179	0.222	0.19	0.186	0.273	0.207	0.272	0.208	0.19	0.194	0.184	0.226	0.177
4	0.138	0.147	0.147	0.118	0.172	0.166	0.163	0.184	0.204	0.192	0.124	0.097	0.117	0.102	0.133	0.118
5	0.183	0.14	0.124	0.168	0.122	0.144	0.141	0.205	0.219	0.172	0.136	0.102	0.116	0.116	0.127	0.111
6	0.175	0.177	0.163	0.222	0.19	0.133	0.179	0.182	0.242	0.207	0.176	0.116	0.135	0.128	0.145	0.122
7	0.19	0.215	0.169	0.226	0.253	0.224	0.17	0.248	0.284	0.285	0.218	0.195	0.204	0.179	0.187	0.206
8	0.243	0.25	0.214	0.282	0.274	0.271	0.282	0.226	0.276	0.297	0.219	0.215	0.245	0.22	0.254	0.206
9	0.214	0.179	0.178	0.186	0.19	0.216	0.22	0.255	0.174	0.264	0.197	0.128	0.216	0.148	0.171	0.141
10	0.199	0.207	0.146	0.237	0.219	0.19	0.173	0.262	0.232	0.201	0.236	0.15	0.214	0.194	0.202	0.175
11	0.142	0.181	0.156	0.165	0.179	0.188	0.163	0.208	0.225	0.219	0.133	0.124	0.15	0.154	0.215	0.134

12	0.22	0.203	0.177	0.234	0.264	0.261	0.249	0.278	0.287	0.281	0.246	0.128	0.209	0.165	0.238	0.177
13	0.169	0.219	0.176	0.205	0.211	0.203	0.206	0.204	0.225	0.276	0.2	0.16	0.135	0.137	0.169	0.17
14	0.15	0.157	0.138	0.219	0.168	0.16	0.179	0.202	0.187	0.248	0.17	0.116	0.168	0.102	0.173	0.133
15	0.219	0.227	0.188	0.198	0.249	0.23	0.232	0.262	0.218	0.278	0.233	0.135	0.187	0.156	0.157	0.182
16	0.236	0.248	0.188	0.232	0.253	0.25	0.25	0.26	0.218	0.299	0.251	0.151	0.226	0.149	0.224	0.141

Step 7: The casual parameters are obtained.

$$R_i = \sum_{j=1}^{n} s_{ij} \qquad \forall i \tag{13}$$

$$C_j = \sum_{i=1}^{n} s_{ij} \qquad \forall j \tag{14}$$

R_i= Sum of rows

C_j= Sum of Column

4.3 Results

The purpose of this study was to analyze the causal links among supply chain BT adoption hurdles using a hybrid of Grey and DEMATEL methodologies. In order to eliminate effects that are considered relatively insignificant a threshold value of 0.1896 was determined by calculating and adding the mean and standard deviation of the values of the total relation matrix. All relationships closer to or exceeding the threshold value are highlighted in Table 7.

Figure 7 shows the digraph representing causal relations of BT adoption barriers for the supply chain. The magnitude of R+C values are presented on the horizontal axis and the vertical axis shows the magnitude of R-C values. The barriers under the causal group can be analyzed based on R-C values. Similarly, the barriers under the effect group can be analyzed based on R+C values. The barriers with negative R-C values are identified as effect group barriers and can be found in the lower half of Figure 2. Positive R-C values are identified as causal group barriers which can be seen in the upper half of Figure 2. The lines connecting these barriers show the correlation among them.

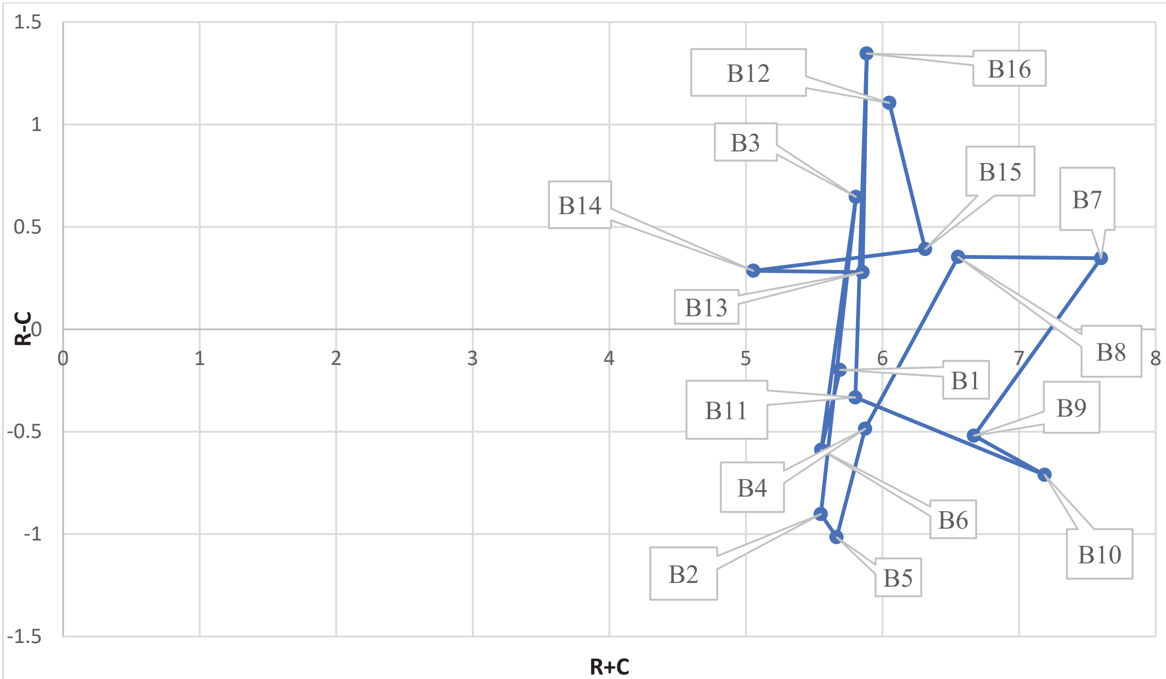

Figure 7: Digraph representing causal relations of BT adoption barriers.

In situations involving complex decision-making, it is common for multiple criteria to be involved. These criteria can either have an impact on other criteria (causal group) or be influenced by certain criteria (effect group), as illustrated in Table 8.

Table 8: Cause and effect parameters of BT adoption barriers for supply chain

Barriers	R	C	R-C	R+C	Cause/Effect
1	2.745144	2.943376	-0.19823	5.68852	Effect
2	2.481278	3.070019	-0.58874	5.551297	Effect
3	3.225865	2.579681	0.646184	5.805547	Cause
4	2.323048	3.225584	-0.90254	5.548632	Effect
5	2.324516	3.339581	-1.01507	5.664098	Effect
6	2.693848	3.179479	-0.48563	5.873327	Effect
7	3.453746	3.100132	0.353614	6.553878	Cause
8	3.973914	3.627011	0.346903	7.600925	Cause
9	3.075356	3.594923	-0.51957	6.67028	Effect
10	3.238183	3.949009	-0.71083	7.187192	Effect
11	2.734325	3.066955	-0.33263	5.801281	Effect
12	3.6153	2.269199	1.346101	5.884499	Cause
13	3.06643	2.787973	0.278458	5.854403	Cause

14	2.670211	2.384744	0.285467	5.054954	Cause
15	3.352149	2.960679	0.39147	6.312828	Cause
16	3.577612	2.47258	1.105032	6.050192	Cause

4.4 Discussion

This section will delve deeper into the outcomes, examining them through the lenses of the causal group barriers, the effect group barriers, and the correlations among barriers to adopting BT in the supply chain.

4.4.1 Causal group barriers

Causal barriers are ranked as per their $(Ri - Cj)\ \forall\ i - j$ values and the priority is as follows 12 > 16 > 3 > 15 > 7 > 8 > 14 > 13 (Table 7). The ranking shows that technical complexity (12), tops the causal list followed by data privacy issues (16), and limited financial capability (3). The technical complexity of BT requires dedicated tools and training thus, unplanned and quick adoption is difficult. It strongly drives many other barriers, and controlling it will ease BT adoption in the supply chain. Technical complexity drives the barriers of other categories such as behavioral, legal, and economic. In line with the literature the result confirms that the limited global familiarity makes it more complex to implement (Wang et. al, 2019; Mathivathanan et al., 2021). Data privacy issue (16) drives a zone of discomfort among stakeholders as sharing all the sensitive information over a distributed network makes it prone to cyber-attacks. It is also due to the unwillingness of the stakeholders to share their confidential information. Limited financial capability (3) is the third most crucial driver for other barriers. Adoption of new technologies often requires funds to gather the resources and continue the complete adoption throughout the network. It adversely impacts the management's decisions regarding BT adoption. Scalability issue (15) drives the barriers such as increased cost (1). The BT is still in its nascent stage thus, scaling it to the entire network of stakeholders is challenging. Regulation uncertainty (7), Lack of expertise (8), and Interoperability issues (14) are other notable causal barriers (Ghode et al., 2023).

4.4.2 Effect group barriers

The top barriers under the effect group are ranked as per their $(Ri + Cj)\ \forall\ i - j$ values as follows 10 > 9 > 6 > 11 > 1 > 5 > 2 > 4. Trust issue (10) tops the list of effect barriers as it is driven by many causal barriers such as technical complexity, data privacy issues, and scalability issues. Limited trust in the adoption of new technology often adversely impacts the success of BT adoption in the supply chain. Deficiency of approach (9) is the second most prominent barrier from the effect group and is driven by causal barriers such as technical complexity, lack of expertise, and Interoperability issues. It reduces the effectiveness of the desired output. Lack of policy for Blockchain Technology (6) holds the third position under the effect group and is driven by causal barriers. The other notable barriers of the effect group are the absence of adaptability (11), Increased costs (1), and non-visibility in the taxation system. The absence of adaptability to the new technology is mainly due to its technical complexity and scalability issues. It shows the rigidness of the system toward necessary changes. Increased cost is driven by technical complexity, scalability issues, regulation uncertainty, lack of expertise, and interoperability issues.

4.4.3 Correlations among BT adoption barriers

It is imperative to acknowledge that the improvement of a single barrier does not necessarily result in the enhancement of the entire system. The rationale behind this phenomenon can be attributed to the interconnectedness that exists among different barriers. The identification of these dependencies is of utmost importance in order to accurately identify barriers within the effect group, and subsequently, barriers that have a causal relationship and can be targeted for improvement in the overall system. $(\mathrm{Ri} + \mathrm{Cj}) \; \forall \, i - \mathrm{j}$ values decide the degree of correlation among BT adoption barriers for the supply chain. the correlation order is 8 > 10 > 9 > 7 > 15 > 16 > 12 > 6 > 13 > 3 > 11 > 1 > 5 > 2 > 4 > 14. Lac of expertise (8) is the most correlated barrier to BT adoption. Due to the initial phase of BT adoption, the expertise required to adopt it at the global supply chain network is limited. Trust issue (10) is the second most correlated BT adoption barrier. The distributed network of the BT fuels it as the data is shared among all the stakeholders. In addition, the technology is still perfecting itself thus there is a lack of confidence in global scale adoption. Deficiency of approach (9) makes the processes of adoption more complex and increases the adoption cost while reducing the chances of successful adoption. Regulation uncertainty is making it difficult to create a unified adoption framework for all the stakeholders in the global supply chain network. In addition, scalability issues, data privacy issues, technical complexity, and lack of policy for blockchain technology are also impact and get impacted by other BT adoption barriers.