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Blockchain Architecture Adoption in Supply Chain Management: A DEMATEL-Based Analysis of Critical Factors

Jankin Abdul Rahman[a], Hai Lee Ooi[b] and Chia Kuang Lee[a*]

[a]*Faculty of Industrial Management, Universiti Malaysia Pahang Al-Sultan Abdullah, Lebuh Persiaran Tun Khalil Yaakob, 26300 Kuantan, Pahang Darul Makmur, Malaysia*
[b]*Edustats Solutions, 33-01 Keck Seng Tower, 203 Jalan Bukit Bintang, 55100 Kuala Lumpur, Malaysia*

C H R O N I C L E

Article history:
Received: October 1, 2023
Received in revised format: January 3, 2024
Accepted: February 23, 2024
Available online:
February 23, 2024

Keywords:
Blockchain architecture
Supply chain management
DEMATEL
Adoption factors
Critical analysis

A B S T R A C T

The uprising of blockchain technology has recently become a trend owing to its prowess to reform the governance of supply chains, offering improved levels of data transparency, traceability, and efficient workflow. The objective drawn on this research is to examine the key determinants that impact the adoption as well as applicability of blockchain technology within the supply chain management context. The Decision-Making Trial and Evaluation Laboratory (DEMATEL) model is tested in this study to inspect and fathom the complex relationships between these components, thereby uncovering their respective significance and interrelationships. The results derived from this study contribute vital insights into the ever-changing landscape of blockchain adoption, with a particular focus on key factors comprising technical competencies, IT infrastructure, interoperability, compatibility, and complexity. The research based on DEMATEL methodology reveals both direct and indirect influences, facilitating a more comprehensive comprehension of these crucial variables. This study is an invaluable resource for industry stakeholders, policymakers, and organizations seeking to embrace blockchain technology into supply chain operations. This study's original intent is to frame an extensive analysis of the key aspects and their interrelationships, offering valuable insights for making well-informed decisions. The overarching aim is to facilitate the seamless assimilation of blockchain architecture into supply chain management systems, promoting effectiveness along with harmony.

1. Introduction

Supply chain management is of paramount significance in the contemporary global competition, which is characterized by its dynamic nature and mutual dependence. It significantly contributes to the success and operational effectiveness of enterprises. The growing intricacy and magnitude of supply networks necessitate the use of inventive measures to augment transparency, efficiency, and security in supply chain operations, which has assumed heightened significance in recent times. Within this setting, the introduction of blockchain architecture arises as a paradigm-shifting technology progression, with the potential to fundamentally alter the realm of supply chain management. This study aims to investigate the complex phenomenon of blockchain adoption in supply chain management, with a specific focus on conducting a DEMATEL-based analysis of critical factors.

The rationale in carrying out this research arises from a profound understanding of the prevalent challenges that afflicted the domain of supply chain management. Traditional supply chain models are commonly associated with little transparency, ineffective procedures, and susceptibilities that, when taken advantage of, can lead to substantial disruptions and financial setbacks. The necessity for a novel approach to tackle these difficulties is evident and persuasive. The utilization of blockchain technology, characterized by its inherent qualities of decentralization, immutability, and transparency, emerges as a highly prospective contender for the reconfiguration of supply chain operations.

* Corresponding author. Tel: +6 09-431 5335
E-mail address: chia@umpsa.edu.my (C. K. Lee)

ISSN 2816-8151 (Online) - ISSN 2816-8143 (Print)

doi: 10.5267/j.jfs.2025.2.004

The significance of this study resides in its capacity to facilitate a more profound comprehension of the variables that impact the implementation of blockchain architecture in the domain of supply chain management. By analyzing and understanding these crucial elements and their interrelationships, organizations can make well-informed decisions and effectively navigate the intricate terrain of blockchain integration with enhanced assurance.

Supply chain management, a critical component of contemporary commerce, involves the strategic coordination and execution of activities related to planning, sourcing, manufacturing, delivering, and managing returns of items and services. Efficient supply chains have a pivotal role in generating cost efficiencies, mitigating risks, and enhancing customer satisfaction. The importance of an effective supply chain is emphasized by the fact that supply networks frequently represent a large proportion of an organization's overall expenses and can have a substantial influence on its competitive edge.

Previous studies in the field of supply chain management have placed significant emphasis on the necessity of using novel measures to improve the levels of transparency and traceability within supply networks. The need to enhance transparency in the supply chain is emphasized in a report published by the World Economic Forum in 2018. The paper suggests that achieving a "single version of the truth" can be facilitated by the implementation of technological breakthroughs, such as blockchain technology.

The blockchain architecture has attracted considerable interest across a wide range of sectors, serving not only as the underlying technology for cryptocurrencies but also as a flexible solution with applicability in other disciplines. The fundamental characteristics of blockchain, such as decentralization, data immutability, smart contracts, and safe data sharing, have expanded its applicability beyond the realm of digital currencies.

Prior scholarly investigations examining the utilization of blockchain technology in the context of supply chain management have emphasized the inherent capacity of blockchain to effectively tackle significant challenges, including but not limited to enhancing transparency, optimizing operational efficiency, and promoting sustainability within supply chain operations. Nevertheless, there are still several areas in research that have not been adequately explored. These areas include the determination of crucial factors that facilitate the adoption decision and their impact, as well as the necessity to tackle difficulties related to scalability, security, and standardization during the adoption process (Liao et al., 2020; Kouhizadeh & Sarkis, 2018).

Hence, the present study aims to elucidate the complex interplay of important factors that impact the adoption of blockchain technology in the domain of supply chain management. The lead objective of this study is to examine factors that facilitate the adoption of blockchain architecture in supply chain management. Specifically, the research aims to identify the stated research questions (RQs):

RQ1: What are the enablers of blockchain architecture adoption in supply chain management?

RQ2: What is the level of influence of identified enablers on the adoption decision?

2. Literature Review

Blockchain technology does hold far-reaching potential for triggering revolutionary improvements across various sectors especially in supply chain management, it has massed ample attention in academia. This literature review direction is to investigate key determinants that impact the adoption together with implementation of blockchain architecture within the context of supply chain management (see Appendix A). It draws upon the broad scope of scholarly studies to offer a thorough and all-encompassing comprehension of this emerging field of study. The adoption of blockchain architecture in supply chain management is a multifaceted and demanding endeavor that desires the presence of diverse crucial factors to ensure its proper execution. The present study aims to identify and delineate five key enablers, including technical competencies, IT infrastructure, interoperability, complexity, and compatibility. The significance of technical competencies in facilitating the integration of blockchain technology into supply chain management has been pointed out by scholars. Several studies (Ahmad et al., 2020; Hsieh et al., 2021; Rathore et al., 2021; Sivarajah et al., 2019) have continuously emphasized the significance of technical abilities such as programming skills, cryptography comprehension, and smart contract development in facilitating compelling implementation of blockchain technology. This highlights the imperative for organizations to allocate resources towards developing these competencies within their workforce to fully leverage the capabilities of blockchain technology in their supply chain activities. The effective adoption of blockchain architecture is contingent upon the underlying IT infrastructure, which includes many components such as hardware, software, and network systems. The assimilation of different various technologies, such as cloud computing (Zhang et al., 2020), edge computing (Jia et al., 2021), the Internet of Things (IoT) (Wang et al., 2021), and advanced analytics using artificial intelligence (AI) (Zhang et al., 2021), has been argued by scholars to have significant implications. These technologies are believed to play crucial roles in facilitating the adoption process. These features contribute to the enhancement of scalability, reduction of latency, and the provision of real-time data, ultimately leading to improvements in data transparency, traceability of data, and efficient workflow within supply chain processes.

Interoperability holds significant importance in the operations of supply chain management, particularly in relation to the adoption of blockchain technology. This is principally associated with diverse range of roles involved, each utilizing distinct blockchain networks. The achievement of seamless interoperability is proposed by researchers through the introduction of cross-chain communication protocols (Zhang et al., 2020), interoperability standards (Fan et al., 2021), middleware solutions (Li et al., 2021), and smart contracts (Sánchez-Rodríguez et al., 2021). These tactics promote the integration of various components and enhance the levels of transparency and traceability within supply chain activities.

The presence of complexity in blockchain technology may pose obstacles, but it can also facilitate the widespread acceptance and adoption of blockchain. The utilization of technology offers a transparent and tamper-proof ledger system (Jiang et al., 2020), thus augmenting security measures (Liu et al., 2019). Additionally, it streamlines supply chain operations and effectively resolves intricacies associated with such processes (Huang et al., 2020). Nevertheless, it is crucial to recognize that the presence of complexity might pose challenges to the acceptance and utilization of a concept or technology. Consequently, it becomes necessary to establish established guidelines and structures to ensure a smooth and effective integration (Dabbaghian et al., 2021). The establishment of compatibility between blockchain architecture and pre-existing systems is a crucial factor that facilitates its successful implementation. According to Yang et al. (2021), there is a scholarly consensus that compatibility plays a crucial role in improving interoperability, minimizing integration expenses, and promoting collaborative efforts across different organizations. However, the resolution of compatibility issues mandates the establishment of standardized protocols and frameworks for seamless integration (Liu et al., 2019). The extant body of scholarly work has revealed several areas in need of further investigation. The gaps highlight the necessity for a more thorough investigation into the difficulties and limitations that could impede the effort of blockchain technology integration. This examination should encompass an analysis that prioritizes the interests of stakeholders, employs robust research methodologies, considers managerial and organizational factors, considers regulatory and legal aspects, evaluates the efficacy of blockchain in tackling specific supply chain challenges, incorporates real-world implementation studies, and assesses the long-term viability of blockchain functions within supply chain operations. The integration of blockchain architecture into supply chain management is a dynamic area of study, characterized by a substantial corpus of scholarly research. The adoption of a particular technology is most often determined by various aspects, including technical abilities, IT infrastructure, interoperability, complexity, and compatibility. These elements are crucial in determining the extent to which technology is adopted. The utilization of a DEMATEL-based methodology is a viable avenue for attaining a full comprehension of the dynamics surrounding the adoption of blockchain technology. The resolution of current research gaps would propel the field forward and provide significant contributions to organizations seeking to integrate blockchain technology into their supply chain operations.

3. Methodology

The achievement of a research venture is inherently connected to the strength and reliability of its research methodology. Detailed explanation of the methodological framework that forms the foundation of the study is discussed here. It aims to clarify the strategy, data collection methods, and analytical tools that were utilized to investigate the research topics. The research employs quantitative research methodology to investigate the various aspects that impact the adoption of blockchain architecture in supply chain management. The main approach for gathering data revolves around the utilization of a survey instrument. By employing this instrument, the study is effectively poised to obtain organized and measurable replies from a group of specialists in the discipline, thereby providing a methodical and uniform approach to gathering data. Hence, the selection of participants is derived from a heterogeneous group of professionals, including individuals with expertise in supply chain management, information technology and blockchain technology. The inclusion of many perspectives within this diversity is essential for the comprehensive analysis of factors that facilitate the adoption of blockchain technology. The study utilizes the Decision-Making Trial and Evaluation Laboratory (DEMATEL) technique as an analytical tool. This methodology demonstrates exceptional proficiency in elucidating intricate causal relationships and interrelationships within the dataset derived from expert assessments. The process systematically establishes hierarchies for evaluation, outlines interdependencies, and offers a visual depiction of the causal connections between variables. The DEMATEL method possesses the advantageous characteristics of flexibility and effectiveness, rendering it well-suited for the analysis of complex decision-making processes within the specific setting of this research. To ensure the accuracy and consistency of collected data, stringent steps are implemented to improve the validity and dependability of the data. The survey questionnaire has been carefully crafted, ensuring that the questions possess face validity. Conducting a pre-test of the questionnaire on a smaller subset of participants aids in the identification and resolution of potential concerns, hence guaranteeing the attainment of clarity and precision in the instrument. The data's veracity is reinforced by the inclusion of expert judgements from a panel of individuals who have extensive knowledge in the fields of supply chain management and blockchain technology. The DEMATEL technique, by assigning equal weight to expert viewpoints and minimizing bias, ensures the reliability of data.

3.1 Data Collection

The study's research design is based on quantitative methodology. This research examines the key factors that facilitate the adoption of blockchain architecture within the context of supply chain management. In order to properly answer the research questions, a systematic and structured technique was devised. Due to the intricate nature of supply chain management and the imperative to comprehend the impact of diverse aspects on the adoption of blockchain architecture, using a quantitative methodology provides a methodical and evidence-based strategy to investigate the study inquiries.

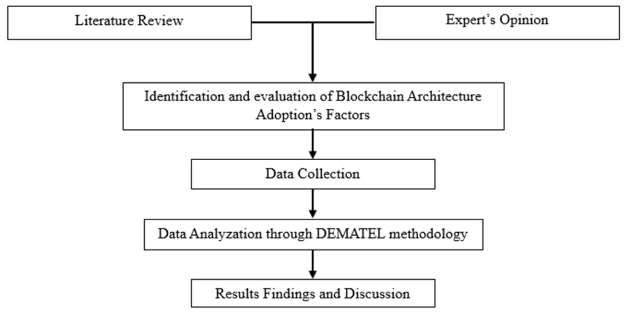

Fig. 1. Proposed Methodology

3.2 DEMATEL Application

The process under consideration is a methodical and organized technique to examine the complex relationships between variables or elements within a certain system. Within the domain of supply chain management and the adoption of blockchain technology, the study's primary focus centers on the significant usefulness of DEMATEL in elucidating the intricate connections among the various elements that influence the decision to adopt.

Within this research structure, the utilization of DEMATEL can be applied to elucidate the intricate network of interconnections and the causal connections in between factors that facilitate the adoption of blockchain architecture. The utilization of DEMATEL enables a thorough comprehension of the interrelationships among the components involved in the adoption choice, as experts offer their perspectives on the influence of these factors.

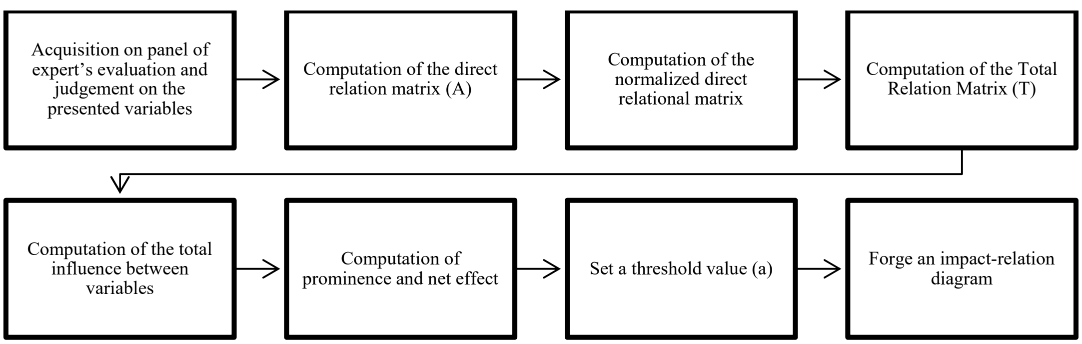

Fig. 2. Process Flow of DEMATEL methodology

Thus, the algorithm of conduct in DEMATEL steps of processes defined as above which totalled up to eight necessary and vital procedures which is inclusive of the evaluation of influence between variables.

4. Data Analysis

The discussion held here outlines the data analysis methodologies employed in this study, with the objective of investigating factors that facilitate the adoption of blockchain architecture in supply chain management. The analysis comprises various essential elements, which include the preparatory phase and first data screening, as well as the implementation of the DEMATEL approach.

4.1 Demographic Analysis

The analysis of the respondents' demographics in this study through the DEMATEL method indicated a heterogeneous group of individuals possessing significant expertise in the fields of supply chain management and blockchain technology. The panel was composed of a group of 25 specialists, with each member having an average of 5-10 years of experience in their respective areas of expertise. The individuals in question possessed diverse educational backgrounds, encompassing bachelor's degrees, master's degrees, and doctoral levels in disciplines of information technology (IT), business administration, management and engineering. The individuals encompassed a variety of positions within the sector, including supply chain managers and blockchain developers, so it reflects numerous facets of the field. The panel of experts consisted of individuals from several sectors, such as manufacturing, logistics, information technology (IT) and a few more to name, thereby providing a comprehensive viewpoint on the adoption of blockchain technology in supply chain management. In terms of geographical distribution, the participants spanned over several areas, with a particular emphasis on individuals with expertise mainly in Kuala Lumpur & Selangor region. This deliberate selection of respondents from these regions was intended to capture the whole nation scope of the study.

The presence of demographic diversity in this context offers a thorough and comprehensive examination of key aspects that impact the adoption of blockchain technology in the management of supply chains.

Table 1
Data on Respondent's Gender

Gender	Number of Respondents
Male	15
Female	10
Total	**25**

Table 1 presents data regarding the distribution of respondents in this survey according to their gender. Among the 25 respondents, there are 15 males and 10 females. The data demonstrates a greater proportion of males in the respondent group, with 60% of the participants being male, compared to 40% who being female. The gender distribution is a crucial demographic variable to consider while examining the findings and formulating conclusions from the study.

Table 2
Data on Respondent's Level of Education

Level of Education	Number of Respondents
High School	0
Diploma	0
Bachelor's Degree	15
Master's Degree	4
Doctoral Degree	1
Total	**25**

Among participants, 15 out of 25 hold a bachelor's degree, suggesting a prevalent educational attainment. This degree is considered fundamental in higher education, indicating a significant portion of participants have achieved at least this level. The inclusion of people with master's degrees denotes subject matter competence and a more sophisticated comprehension. Remarkably, one of the participants holds a Doctoral Degree, emphasizing the potential for profound perspectives in the study.

Table 3
Data on Respondent's Job Position

Job Position Level	Number of Respondents
Supply Chain Manager	10
Blockchain Developer/Expert	2
Logistics Disposition Manager	8
IT Specialist	5
Total	**25**

The sample includes 10 "Supply Chain Managers", 2 "Blockchain Developer/Experts", 8 "Logistics Disposition Managers", and 5 specializing in "IT". Table 3 is crucial for understanding respondents' professional diversity in the study context. Analyzing job distribution provides insights into diverse knowledge and opinions on blockchain in supply chain management. The data is valuable due to varying influence and understanding across different job positions regarding the topic.

Table 4
Data on Respondent's Industry Affiliation

Industry Affiliation	Number of Respondents
Semiconductor	8
Logistics/Transportation	6
Oil & Gas	4
Financial Services	3
IT Services	4
Total	**25**

Among the participants, 8 were linked to the "Semiconductor" industry, 6 with "Logistics/Transportation", 4 with "Oil & Gas", 3 in "Financial Services", and 4 with "IT Services". The study gains insights into blockchain adoption in supply chain management through participants' industry expertise. Diverse backgrounds contribute unique perspectives, adding value to the study's research objectives. The data is significant for evaluating how industry affiliation influences key factors in adopting blockchain technology in supply chain management.

Table 5
Data on Respondent's Geographical Location

Geographical Location	Number of Respondents
Kuala Lumpur	12
Selangor	7
Penang	4
Kedah	2
Total	**25**

Table 5 presents a comprehensive overview of geographical locations in the research, crucial for assessing variations in blockchain adoption in supply chain management across countries. Geographical diversity among respondents offers insights into regional viewpoints and potential differences in practices and issues related to blockchain implementation. The sample includes 12 participants from "Kuala Lumpur", 7 from "Selangor", 4 from "Penang", and 2 from "Kedah".

Table 6
Data on Respondent's Expertise Level

Expertise Level	Number of Respondents
Novice	4
Intermediate	10
Advanced	11
Total	**25**

Table 6 classifies participants into proficiency levels based on their skill and familiarity with blockchain adoption in supply chain management. This data is crucial for analyzing how different experience levels can influence views and insights on implementing blockchain technology in the supply chain. The study may explore whether there are differing viewpoints among experts and beginners regarding key aspects or challenges in this domain.

4.2 DEMATEL Computation

The DEMATEL technique is a structural analysis method that is commonly employed to discern and visually represent the causal linkages that exist between various variables (Shieh et al., 2010; Yang et al., 2008). In this context, the DEMATEL method was employed to determine the magnitude and orientation of the impact among the factors that facilitate the adoption of blockchain architecture in the domain of supply chain management.

4.2.1 Computation of the Direct Relation Matrix (A)

After expert's evaluation and judgement has been presented and collected based on forementioned factors present in this study, the data has been further evaluated and computed into direct relation matrix (see Appendix B).

$$A = \frac{1}{k}\sum_{k-1}^{k} Ak$$

4.2.2 Computation of Normalized Direct Relation Matrix (D)

It becomes a crucial component for further analysis in the DEMATEL framework when the Normalized Direct Relation Matrix is computed. Understanding of causal relationships and the relative significance of factors used in decision-making are improved by this matrix. By employing this matrix, assessment accuracy is increased, enabling informed decision-making and improving problem-solving and decision-making skills (see Appendix C). Next, implement a formula that determines the sum of the components in each matrix line to normalize direct relation matrix A. The equation yields the maximum sum (S):

$$S = \max_{1\leq j\leq n} \sum_{j=1}^{n} zij$$

Subsequently, the after the computation above, the normalized direct relation matrix will undergo another computation through the applied formula below:

$$B = \frac{1}{s}A$$

4.2.3 Computation of Total Relation Matrix (T)

This approach integrates both the explicit and implicit correlations among the various components or criteria being examined. The computation of T involves a sequence of mathematical procedures that utilize the Normalized Direct Relation

Matrix and the Normalized Total Relation Matrix. This process allows for the encapsulation of the comprehensive influence of each element on all others (see Appendix C).

The process of interpreting the Total Relation Matrix includes the identification and analysis of patterns and insights that are crucial for making informed and effective decisions. The provided information offers a full perspective on the interplay between individual elements and the overall system, as well as the subsequent propagation of these influences within the network. By conducting a thorough investigation and analysis, decision-makers have the ability to discover key components that possess substantial control or influence over other elements, as well as those that are more susceptible to being impacted.

$$T = B + B^2 + B^3 + B^4 \ldots = B(1 - B)^{-1}$$

4.2.4 Computation of Total Influence between Variables (Ri) and (Cj)

The equation below illustrates how to consciously compute the total impact of a variable (i) on others by adding up the components in its row (Ri) in the total relation matrix (T). In a similar manner, the total of the elements in the appropriate column (Cj) of the same matrix (T) represents the impact that variables (j) derived from others.

$$R_i = \sum_{j-1}^{n} t_{ij};\ i, j\ \in [1, n]$$

$$C_j = \sum_{i=1}^{n} t_{ij};\ i, j\ \in [1, n]$$

Table 7
Net Effect (Causes)

Rank	Enabler's Elements	Causes
1	E22 - Open to changes and adaptation (Compatibility)	1.895
2	E15 - Network Enhancement (Interoperability)	0.766
3	E21 - Common Objectives (Compatibility)	0.647
4	E20 - Common Rules on Data Disclosure (Compatibility)	0.524
5	E7 - Hardware and Software Compatibility (IT Infrastructure)	0.508
6	E23 - New Technology Standard (Complexity)	0.454
7	E14 – Traceability (Interoperability)	0.427
8	E19 - Transparency and Auditability (Compatibility)	0.386
9	E18 - Credible and Accurate Data (Compatibility)	0.366
10	E8 - Cybersecurity and Resilience (IT Infrastructure)	0.347
11	E13 - Increased Control (Interoperability)	0.342
12	E10 – Scalability (IT Infrastructure)	0.282
13	E5 - Technological Capabilities (IT Infrastructure)	0.169
14	E6 - Financial Resources (IT Infrastructure)	0.142
15	E9 - Design Variables (IT Infrastructure)	0.117
16	E11 - Rules and Standard (Interoperability)	0.012

Table 7 ranks enabling aspects based on their net causal impacts on blockchain adoption in supply chain management. Numeric values indicate both the size and direction of influence. Higher values denote a more favorable impact. Key areas with significant positive impact include compatibility, interoperability, IT infrastructure, and complexity. Compatibility covers openness to change and common objectives, while interoperability involves network enhancement and traceability. IT infrastructure includes hardware and software compatibility, scalability, cybersecurity, and financial resources. Complexity relates to new technology standards. The findings emphasize the importance of factors like compatibility, interoperability, and a robust IT infrastructure in promoting blockchain adoption. This insight is valuable for decision-makers implementing blockchain solutions in the industry.

Table 8
Net Effect (receiver)

Rank	Enabler's Elements	Effect
1	E2 - Technical Expertise (Technical Competencies)	-1.261
2	E12 – Adaptability (Interoperability)	-1.167
3	E27 - Technological Volatility (Complexity)	-1.021
4	E3 - Integral Education and Training (Technical Competencies)	-0.841
5	E25 - Rules and Governance (Complexity)	-0.790
6	E17 - Business Process Standardization (Compatibility)	-0.653
7	E24 - Application into SCM (Complexity)	-0.524
8	E4 - Quality and Integrity (Technical Competencies)	-0.523
9	E1 - Technical Literacy (Technical Competencies)	-0.260
10	E26 - Complicated Tools and Equipment (Complexity)	-0.257
11	E16 - Verifiability of transactions (Interoperability)	-0.085

Table 8 hierarchically arranges enabling elements based on their influence on outcomes in the implementation of blockchain in supply chain management. Negative values in the "Effect" column indicate potential obstacles to adoption. Factors like technical skill, flexibility, technological instability, and complexity have the most significant adverse effects. Conversely, factors linked to technical competence, quality, and integrity have a comparatively lesser detrimental impact. The data highlights challenges in adoption related to technical proficiency and flexibility. Decision-makers must carefully address these challenges for successful integration of blockchain.

4.2.5 Compute a Threshold value (a)

Careful consideration is crucial in selecting the threshold value (a), and it depends on the investigation's context and objectives. This determination can stem from pre-existing knowledge, statistical methods, or professional expertise. The chosen threshold value significantly impacts DEMATEL analysis outcomes and the clarity of the impact-relation diagram. For this comparison, a threshold value of 0.622 is employed. Complex systems often involve numerous variables and interdependencies. In this study, the extensive interconnectedness is particularly noteworthy. The use of a threshold helps manage complexity by focusing on the most influential connections. This simplification process enhances clarity and makes it easier to communicate findings.

$$\alpha = \frac{\sum_{i=1}^{n}\sum_{j=1}^{n}[tij]}{N}$$

Table 9
Top 10 Highest Values

Rank	Relationships	Values
1	E1 – E7	0.703
2	E2 – E1	0.693
3	E1 – E22	0.690
4	E1 – E6	0.686
5	E1 – E15	0.685
6	E2 – E7	0.685
7	E3 – E7	0.684
8	E1 – E8	0.682
9	E2 – E6	0.681
10	E2 – E15	0.681

Table 9 analyzes the ten most significant values representing interactions between elements (E1, E2, E3, E6, E7, E8, E15, and E22). Values indicate the strength of relationships, with higher values signifying a more robust connection between variables. For instance, a strong relationship is observed between E1 (Technical Literacy) and E7 (Hardware and Software Compatibility), with a correlation coefficient of 0.703. This suggests a statistically significant association between technical literacy and hardware/software compatibility. The table provides an overview of diverse interaction levels, revealing the relative impact of certain elements within the framework of blockchain adoption. Understanding these interactions is crucial for making informed judgments and devising effective implementation strategies.

4.2.6 Compute Impact Relation Diagram

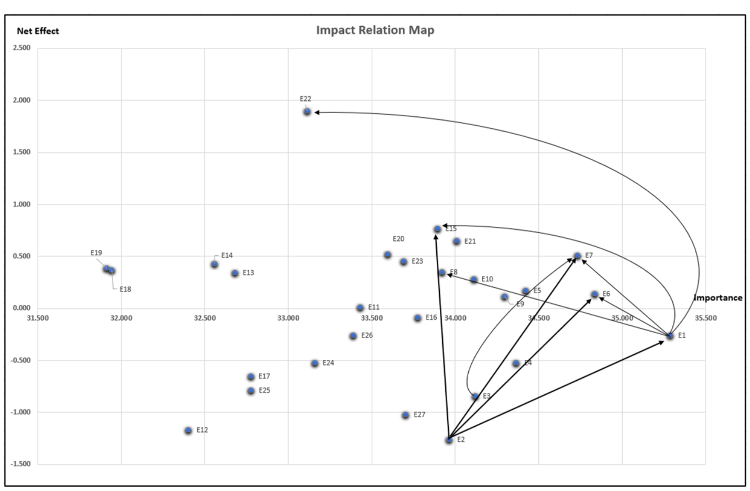

Fig. 3. The Impact Relation Diagram for 10 highest relationships value

4.3 Sensitivity Analysis

In this scenario, the sensitivity analysis assesses the impact of adding five values to the top ten used for factor relationships. It evaluates the significance of these additional components on the overall impact relationship diagram, starting by examining the fundamental top 10 factor associations. This sheds light on crucial interactions among elements like technical competencies, IT infrastructure, compatibility, interoperability, and complexity. The sensitivity analysis explores how these extra values influence the overall impact relationships within this set, addressing questions such as: Do these new components exert more influence than certain factors previously identified in the top 10? Do these changes significantly alter the dynamics of the impact relation diagram? This analysis can determine if including these additional parameters shifts the investigation's scope significantly. It offers a comprehensive overview of the relative significance of the top 15 values, aiding researchers, and decision-makers in identifying elements with the greatest influence for prioritized strategies or further examination.

Table 10
Top 15 Highest Values

Rank	Relationships	Values
1	E1 – E7	0.703
2	E2 – E1	0.693
3	E1 – E22	0.690
4	E1 – E6	0.686
5	E1 – E15	0.685
6	E2 – E7	0.685
7	E3 – E7	0.684
8	E1 – E8	0.682
9	E2 – E6	0.681
10	E2 – E15	0.681
11	E6 – E1	0.680
12	E27 – E22	0.680
13	E4 – E1	0.679
14	E4 – E6	0.679
15	E1 – E21	0.678

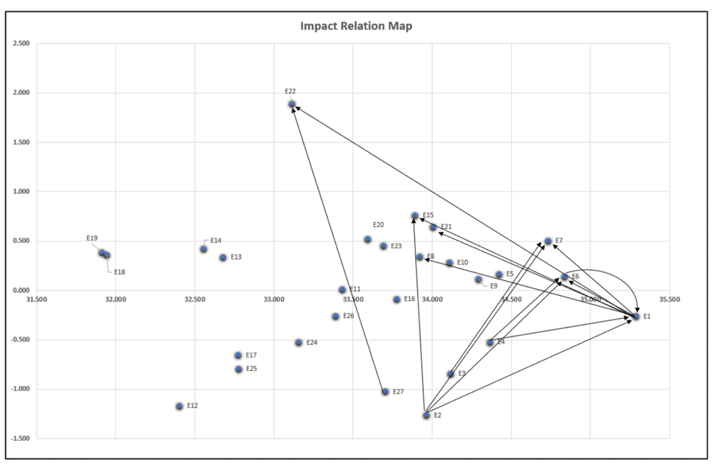

Fig. 4. Revised Impact Relation Diagram with the top 15 highest value

4.4 Causal Loop Diagram

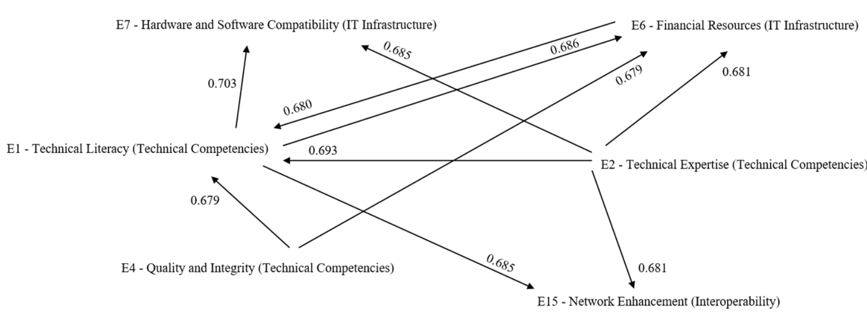

Fig. 5. Causal Loop Diagram

Technical Literacy (E1) influences Financial Resources (E6), subsequently affecting Hardware and Software Compatibility (E7) and Network Enhancement (E15) in a positive feedback loop. This loop suggests that improved technical literacy leads to more financial resources, enabling better compatibility and ultimately enhancing network interoperability.

Technical Expertise (E2) influences Technical Literacy (E1), creating cascading effects on Financial Resources (E6), Hardware and Software Compatibility (E7), and Network Enhancement (E15). This underscores the importance of technical expertise in enhancing these variables.

Quality and Integrity in Technical Skills (E4) significantly impacts Technical Literacy (E1) and extends to Financial Resources (E6). Improving quality and integrity in technical skills can potentially augment financial resources.

The relationship between Financial Resources (E6) and Technical Literacy (E1) demonstrates that financial resources facilitate the development of technical competencies.

Compatibility of hardware and software (E7) and Network Enhancement (E15) are exogenous, not influenced by other system aspects. The causal loop diagram visually depicts the interconnections and influences among the components, aiding in understanding the complex dynamics within the study scope.

5. Results and discussions

The investigation uncovered key factors crucial for successful blockchain implementation, including “Technical Literacy” and “Financial Resources”. These elements are interrelated within a larger ecosystem. Correlation analysis revealed intricate dynamics between variables, emphasizing that blockchain adoption relies on both individual elements and their cumulative impact. The relationships like “Quality and Integrity” with “Technical Literacy” or “Technical Expertise” with “Technical Literacy” stress the importance of fostering a culture of comprehension and proficiency within organizations. External elements like “Hardware and Software Compatibility” and “Network Enhancement” were found to be fundamentally significant, capable of exerting substantial influence on the entire blockchain system once established.

5.1 Ecosystem of Interrelationships Factor

The study reveals complex interdependencies among key elements influencing blockchain implementation in supply chain management. Success or challenges are not solely determined by individual factors but by their interplay. For instance, “Technical Literacy” (E1) significantly influences “Financial Resources” (E6), impacting “Hardware and Software Compatibility” (E7), emphasizing the need to consider these elements as part of a larger ecosystem. Additionally, “Quality and Integrity” (E4) is linked to “Technical Literacy” (E1), suggesting that improving data quality can enhance workforce tech literacy. The connection between “Technical Expertise” (E2) and “Technical Literacy” (E1) implies that tech experts can enhance overall workforce tech proficiency. These relationships emphasize the importance of a holistic approach to blockchain adoption, focusing on creating an environment where the workforce understands and values technology. The study underscores the need for careful planning and readiness in critical areas like "Hardware and Software Compatibility" (E7) and "Network Enhancement" (E15), which have significant external impacts. In summary, the findings highlight the nonlinear, relationship-driven nature of blockchain adoption in supply chain management, accentuate the relevance of a harmonious ecosystem for successful integration.

5.2 Sensitivity to Technical Competencies

The research highlights the crucial role of technical proficiency in successfully adopting blockchain technology in supply chain management. Proficiency is essential for designing, implementing, and maintaining blockchain systems, extending beyond IT teams to ensure a widespread understanding across the organization. Cultivating a culture of technical literacy and promoting collaboration across diverse disciplines is vital. Organizations can empower their employees by investing in skill development through training programs, workshops, and relevant certifications. In cases requiring specialized expertise, recruiting blockchain experts is essential. These experts play a key role in guiding decision-making, platform selection, adherence to best practices, and governance, contributing to the effective use of blockchain in supply chain management. Furthermore, technical proficiency significantly influences organizational decision-making processes. Individuals knowledgeable in blockchain principles make informed decisions about blockchain solutions, aligning them with supply chain needs and governance. This emphasizes that the success of blockchain technology relies not only on its technical aspects but also on the proficiency of individuals overseeing its implementation and the organization's commitment to fostering comprehensive blockchain knowledge at all levels.

5. 3 High Interdependence

The research emphasizes the crucial role of technical proficiency in the successful implementation of blockchain technology in supply chain management. It spans various skills essential for handling the intricacies of blockchain, from design to maintenance. Importantly, it stresses the necessity for broad technical literacy across the organization, fostering an innovative and collaborative culture beyond IT teams. Organizations should actively invest in skill development through training, workshops, and certifications to ensure this proficiency. In certain cases, recruiting specialized experts becomes essential for effective leadership in blockchain initiatives, guiding decisions, platform selection, and governance. Ultimately, the study underscores that the success of blockchain in supply chain management relies on personnel possessing technical expertise and a comprehensive understanding of its potential, extending beyond technical considerations.

5.4 Financial Resources as Catalyst

This key finding underscores the pivotal role of financial resources in expediting the adoption of blockchain technology. Organizations with ample financial means can readily invest in blockchain development, infrastructure, and talent, thus accelerating implementation. Financial resources are instrumental in developing technical competence through staff training and recruitment of experts. They also enable the integration of blockchain with existing systems, often complex aspect of implementation. Scalability, critical for supply chain fluctuations, is achievable with financial backing. Additionally, funding ensures data quality and cybersecurity measures, safeguarding supply chain data. It grants organizations a competitive edge by allowing faster adoption, leading to market distinctiveness. Financial resources also empower organizations to adapt to emerging trends and invest in research and development for innovation. In essence, this conclusion reaffirms that financial resources are a pivotal driver in blockchain integration, expediting various adoption facets and granting organizations a competitive advantage in this rapidly evolving field.

5.5 Long-Term Implications

The integration of blockchain technology has yielded not only immediate benefits but also substantial long-term consequences. These findings emphasize the extensive influence of blockchain, transforming supply chain operations and strategies in the long run. Key long-term impacts include enhanced data integrity, end-to-end visibility, trust, collaboration, streamlined compliance and auditing, resilience, innovation, and disruptive mitigation. Blockchain fosters resilient supplier and customer relationships, sustainability efforts, and environmental impact mitigation. In summary, this discovery underscores the lasting significance of blockchain in supply chain management, affecting data reliability, transparency, trust, innovation, connections, and sustainability in the evolving supply chain landscape.

6. Conclusions

This work contributes significantly to academia and practical applications, expanding the theoretical framework of blockchain implementation in supply chain management. It enhances research methods, fosters interdisciplinary understanding, and supports collaboration across academic fields. Practically, the framework informs strategic decision-making, mitigates risks, optimizes resource allocation, and underscores the holistic approach to blockchain implementation. Emphasizing strategic planning, education's role, cybersecurity, and practical methodologies like Impact Relation and Causal Loop Diagrams, this research bridges academia and real-world applications.

Limitations include potential response and recall bias in data collection, a scope confined to supply chain management, and uncertain generalizability to other industries. Complex correlations among influencing elements lack a complete assessment framework. Expanding data sources beyond surveys and interviews, considering events like the COVID-19 pandemic, and addressing cultural and organizational factors could enhance future research. A comprehensive understanding may be achieved through advanced modelling methodologies like system dynamics or network analysis. Comparative studies across industries and the use of real-time data sources are crucial for up-to-date insights and addressing new challenges.

Understanding cultural and organizational impacts necessitates qualitative methodologies such as ethnographic research. In-depth interviews can explore the influence of organizational culture, leadership, and employee beliefs on technology adoption. Longitudinal research is vital for evaluating the enduring effects of blockchain implementation on supply networks. This encompasses efficacy, transparency, and resilience. These insights are valuable for stakeholders grappling with the challenges of integrating blockchain technology into supply chain management.

Acknowledgements

The authors would like to thank the Ministry of Higher Education (Malaysia) for providing financial support under the Prototype Research Grant Scheme (PRGS) No. PRGS/1/2023/SS06/UMP/02/1 (University Reference RDU230801) and Universiti Malaysia Pahang Al-Sultan Abdullah for computer laboratory facilities.

References

Ahmad, A., Javaid, N., & Alam, M. (2020). Blockchain technology for supply chain management: A systematic literature review. *Journal of Cleaner Production*, *258*, 120502.

Alkhater, N., Walters, R., & Wills, G. (2018). An empirical study of factors influencing cloud adoption among private sector organisations. *Telematics and Informatics*, *35*(1), 38– 54. https://doi.org/10.1016/j.tele.2017.09.017

Babich, V., & Hilary, G. (2019). Distributed Ledgers and Operations: What Operations Management Researchers Should Know about Blockchain Technology. *Manufacturing and Service Operations Management*, *22*(2), 223-240. https://doi.org/10.1287/msom.2018.0752

Batubara, F. R., Ubacht, J., & Janssen, M. (2018). Challenges of blockchain technology adoption for e-government: A systematic literature review. *Association for Computing Machinery*, *76*, 1-9. https://doi.org/10.1145/3209281.3209317

Bealt, J., Fernández Barrera, J. C., & Mansouri, S. A. (2016). Collaborative relationships between logistics service providers and humanitarian organizations during disaster relief operations. *Journal of Humanitarian Logistics and Supply Chain Management*, *6*(2), 118–144. https://doi.org/10.1108/JHLSCM-02-2015-0008

Behnke, K., & Janssen, M. F. W. H. A. (2020). Boundary conditions for traceability in food supply chains using blockchain technology. *International Journal of Information Management*, *52*, 101969. https://doi.org/10.1016/j.ijinfomgt.2019.05.025

Chang, S. E., & Chen, Y. (2020). When blockchain meets supply chain: A systematic literature review on current development and potential applications. IEEE Access, *8*, 62478–62494. https://doi.org/10.1109/ACCESS.2020.2983601

Chang, S.-I., & Chen, H.-L. (2015). The application of DEMATEL method in exploring the critical factors affecting the adoption of cloud computing. *Journal of Business Research*, *68*(9), 1946-1953.

Chen, J., Wang, M., & Su, X. (2021). Hybrid blockchain-based secure data sharing and collaboration framework for industry 4.0 supply chain management. *Journal of Cleaner Production, 313*, 127936.

Chittipaka, V., Kumar, S., Sivarajah, U., Bowden, J. L.-H., & Baral, M. M. (2022). Blockchain technology for supply chains operating in emerging markets: An empirical examination of technology-organization-environment (TOE) framework. *Annals of Operations Research*, *327*(1), 465–492. https://doi.org/10.1007/s10479-022-04801-5

Chod, J., Trichakis, N., Tsoukalas, G., Aspegren, H., & Weber, M. (2020). On the financing benefits of supply chain transparency and blockchain adoption. *Management Science*, *66*(10), 4378–4396. https://doi.org/10.1287/mnsc.2019.3434

Clohessy, T., & Acton, T. (2019). Investigating the influence of organizational factors on blockchain adoption: An innovation theory perspective. *Industrial Management and Data Systems*, *119*(7), 1457–1491. https://doi.org/10.1108/IMDS-08-2018-0365

Dabbaghian, V., Gholami, R., Alikhani, A., & Huang, Q. (2021). Blockchain in supply chain management: A systematic review of the literature and future research directions. *International Journal of Information Management*, *56*, 102233.

Deepa, N., Pham, Q. V., Nguyen, D. C., Bhattacharya, S., Prabadevi, B., Gadekallu, T. R., Maddikunta, P. K. R., Fang, F., & Pathirana, P. N. (2022). A survey on blockchain for big data: Approaches, opportunities, and future directions. *Future Generation Computer Systems*, *131*, 209–226. https://doi.org/10.1016/j.future.2022.01.017

Fan, Y., Tan, X., Tang, Y., & Huang, S. (2021). The research of blockchain technology based on supply chain interoperability. *Journal of Physics*, 1864(1), 012017.

Galal, H. S., & Youssef, A. M. (2018). Verifiable Sealed-Bid Auction on the Ethereum Blockchain. *IACR Cryptol ePrint Arch*, *704*, 1-14.

Gökalp, E., Gökalp, M. O., & Çoban, S. (2022). Blockchain-Based Supply Chain Management: Understanding the Determinants of Adoption in the Context of Organizations. *Information Systems Management*, *39*(2), 100–121. https://doi.org/10.1080/10580530.2020.1812014

Gordon, W. J., & Catalini, C. (2018). Blockchain Technology for Healthcare: Facilitating the Transition to Patient-Driven Interoperability. *Computational and Structural Biotechnology Journal*, *16*, 224–230. https://doi.org/10.1016/j.csbj.2018.06.003

Guan, X., Chen, X., Liu, J., & Zhuang, Y. (2019). Critical factors for adopting blockchain technology in the food supply chain: A DEMATEL approach. *Food Control*, *102*, 184- 197.

Harrison, A., van Hoek, R., & Hoek, van. (2008). *Logistics Management and Strategy: Competing Through the Supply Chain.* New Jersey, US. Prentice Hall Financial Times.

Hitaj, B., Ateniese, G., & Perez-Cruz, F. (2017). Deep Models under the GAN: Information leakage from collaborative deep learning. *Association for Computing Machinery*, 603–618. https://doi.org/10.1145/3133956.3134012

Hsieh, H. P., Lee, M. H., & Liao, C. N. (2021). Exploring the critical factors for blockchain adoption in supply chain management: A fuzzy DEMATEL-based approach. Sustainability, *13*(3), 1272.

Hu, X., Zhang, Q., Liu, Y., & Zhan, S. (2020). A survey on the applications of blockchain technology in supply chain management: Potentials and challenges. *Sustainability*, *12*(17), 6952.

Huang, J., Li, M., Li, Z., Li, L., & Li, Y. (2020). Blockchain in supply chain management: A review, a proposed framework and future research directions. *International Journal of Production Research*, *58*(7), 2139-2157.

Hughes, L., Dwivedi, Y. K., Misra, S. K., Rana, N. P., Raghavan, V., & Akella, V. (2019). Blockchain research, practice and policy: Applications, benefits, limitations, emerging research themes and research agenda. *International Journal of Information Management*, *49,* 114–129. https://doi.org/10.1016/j.ijinfomgt.2019.02.005

Iansiti, M., & Lakhani, K. R. (2017). *The truth about blockchain: It will take years to transform business, but the journey begins now*. https://hbr.org/2017/01/the-truth-about-blockchain

Janssen, M., Weerakkody, V., Ismagilova, E., Sivarajah, U., & Irani, Z. (2019). A framework for analysing blockchain technology adoption: Integrating institutional, market and technical factors. *International Journal of Information Management*, *50*, 302–309. https://doi.org/10.1016/j.ijinfomgt.2019.08.012

Jia, K., Zhang, Y., Yu, C., Jiang, X., & Wang, L. (2021). Edge computing based blockchain architecture for Internet of Things enabled supply chain management. *IEEE Transactions on Industrial Informatics, 17*(2), 1023-1033.

Jiang, P., Guo, Y., Sun, Y., & Chen, X. (2020). Blockchain-based supply chain finance: A systematic review of the literature and future research directions. *International Journal of Production Research*, *58*(15), 4728-4746.

Kamble, S. S., Gunasekaran, A., & Sharma, R. (2020). Modeling the blockchain enabled traceability in agriculture supply chain. *International Journal of Information Management*, 52, 101967. https://doi.org/10.1016/j.ijinfomgt.2019.05.023

Kamble, S., Gunasekaran, A., & Arha, H. (2019). Understanding the Blockchain technology adoption in supply chains-Indian context. *International Journal of Production Research*, *57*(7), 2009–2033. https://doi.org/10.1080/00207543.2018.1518610

Kaparthi, S., & Bumblauskas, D. (2020). Designing predictive maintenance systems using decision tree-based machine learning techniques. *International Journal of Quality and Reliability Management*, *37*(4), 659–686. https://doi.org/10.1108/IJQRM-04-2019-0131

Kearns, G. S., & Sabherwal, R. (2006). Strategic alignment between business and information technology: A knowledge-based view of behaviors, outcome, and consequences. *Journal of Management Information Systems*, *23*(3), 129–162. https://doi.org/10.2753/MIS0742-1222230306

Kleijnen, M., Lee, N., & Wetzels, M. (2009). An exploration of consumer resistance to innovation and its antecedents. *Journal of Economic Psychology*, *30*(3), 344–357. https://doi.org/10.1016/j.joep.2009.02.004

Koteska, B., Karafiloski, E., Mishev, A., & Cyril, U. S. (2018). Blockchain Implementation Quality Challenges: A Literature Review. *SQAMIA*, 1938, 1-8.

Kouhizadeh, M., Saberi, S., & Sarkis, J. (2021). Blockchain technology and the sustainable supply chain: Theoretically exploring adoption barriers. *International Journal of Production Economics*, *231*, 107831. https://doi.org/10.1016/j.ijpe.2020.107831

Kraft, D. (2016). Difficulty control for blockchain-based consensus systems. *Peer-to-Peer Networking and Applications*, *9*(2), 397–413. https://doi.org/10.1007/s12083-015-0347-x

Kritchanchai, D., Hoeur, S., & Engelseth, P. (2018). Develop a strategy for improving healthcare logistics performance. *Supply Chain Forum: An international Forum*, *19*(1), 55–69. https://doi.org/10.1080/16258312.2017.1416876

Kshetri, N. (2017). Blockchain's roles in strengthening cybersecurity and protecting privacy. *Telecommunications Policy*, *41*(10), 1027–1038. https://doi.org/10.1016/j.telpol.2017.09.003

Kshetri, N. (2018). Blockchain's roles in meeting key supply chain management objectives. *International Journal of Information Management*, *39*, 80-89. https://doi.org/10.1016/j.ijinfomgt.2017.12.005

Kshetri, N. (2021). Blockchain and sustainable supply chain management in developing countries. *International Journal of Information Management*, *60*, 102376. https://doi.org/10.1016/j.ijinfomgt.2021.102376

Kshetri, N., Voas, J., & Bendiab, A. T. (2020). Blockchain-enabled decentralization of supply chains: Conceptual framework, use cases and implications. *International Journal of Information Management*, *52*, 102055.

Lacity, M. C. (2018). 17:3) | Addressing Key Challenges to Making Enterprise Blockchain Applications a Reality. MIS Quarterly Executive, *17*(3), 201-222.

Leimeister, J. M., Knebel, U., & Krcmar, H. (2007). RFID as enabler for the boundless real- time organisation: empirical insights from Germany. *International Journal of Networking and Virtual Organisations*, *4*(1), 45-64. https://doi.org/10.1504/IJNVO.2007.012082

Li, S., Wang, S., & Zhu, L. (2021). Middleware-enabled interoperability of blockchain-based supply chain systems. *Future Generation Computer Systems*, *114*, 404-413.

Li, X., Chen, H., & Zhang, L. (2019). A DEMATEL-based evaluation of the relationships among key success factors for green supply chain management implementation in China. *Journal of Cleaner Production*, *235*, 625-634.

Lin, N. (1999). Building a Network Theory of Social Capital. *CONNECTIONS*, *22*(1), 28–51.

Lin, Y.-P., Petway, J., Anthony, J., Mukhtar, H., Liao, S.-W., Chou, C.-F., & Ho, Y.-F. (2017). Blockchain: The Evolutionary Next Step for ICT E-agriculture. *Environments*, *4*(3), 50. https://doi.org/10.3390/environments4030050

Liu, X., Ma, Y., Huang, L., & Liu, J. (2019). Blockchain-based security framework for supply chain finance. *Future Generation Computer Systems, 98*, 112-123.

Mainelli, M., & Smith, M. (2015). Sharing ledgers for sharing economies: an exploration of mutual distributed ledgers (aka blockchain technology). Journal of Financial Perspectives, *3*(3), 38-58.

Martin, S. L., Javalgi, R. (Raj) G., & Ciravegna, L. (2020). Marketing capabilities and international new venture performance: The mediation role of marketing communication and the moderation effect of technological turbulence. *Journal of Business Research*, *107*, 25–37. https://doi.org/10.1016/j.jbusres.2019.09.044

Mendling, J., Weber, I., van der Aalst, W., Brocke, J. vom, Cabanillas, C., Daniel, F., Debois, S., di Ciccio, C., Dumas, M., Dustdar, S., Gal, A., García-Bañuelos, L., Governatori, G., Hull, R., la Rosa, M., Leopold, H., Leymann, F., Recker, J., Reichert, M., & Zhu, L. (2018). Blockchains for business process management - Challenges and opportunities. *ACM Transactions on Management Information Systems*, *9*(1), 1-16. https://doi.org/10.1145/3183367

Meng, W., Li, W., Tug, S., & Tan, J. (2020). Towards blockchain-enabled single character frequency-based exclusive signature matching in IoT-assisted smart cities. *Journal of Parallel and Distributed Computing*, *144*, 268–277. https://doi.org/10.1016/j.jpdc.2020.05.013

Moezkarimi, Z., Abdollahei, F., & Arabsorkhi, A. (2019). Proposing a Framework for Evaluating the Blockchain Platform. *IEEE*, *5*, 152-160. https://doi.org/10.1109/ICWR.2019.8765280

Montecchi, M., Plangger, K., & Etter, M. (2019). It's real, trust me! Establishing supply chain provenance using blockchain. *Business Horizons*, *62*(3), 283–293. https://doi.org/10.1016/j.bushor.2019.01.008

Mylrea, M., Nikhil, S., & Gourisetti, G. (2017). Blockchain for Smart Grid Resilience: Exchanging Distributed Energy at Speed, Scale and Security. *IEEE,* RWS, 18-23. https://doi.org/10.1109/RWEEK.2017.8088642

Narayanan, A., Bonneau, J., Felten, E., Miller, A., & Goldfeder, S. (2016). *Bitcoin and Cryptocurrency Technologies: A Comprehensive Introduction*. New Jersey, US. Princeton University Press.

Oliveira, T., & Fraga Martins, M. (2011). Literature Review of Information Technology Adoption Models at Firm Level. *The Electronic Journal Information Systems Evaluation*, *14*(1), 110.

Ølnes, S., Ubacht, J., & Janssen, M. (2017). Blockchain in government: Benefits and implications of distributed ledger technology for information sharing. *Government Information Quarterly*, *34*(3), 355–364. https://doi.org/10.1016/j.giq.2017.09.007

Öztürk, C., & Yildizbaşi, A. (2020). Barriers to implementation of blockchain into supply chain management using an integrated multi-criteria decision-making method: a numerical example. *Soft Computing*, *24*(19), 14771–14789. https://doi.org/10.1007/s00500-020-04831-w

Park, A., & Li, H. (2021). The effect of blockchain technology on supply chain sustainability performances. *Sustainability*, *13*(4), 1726. https://doi.org/10.3390/su13041726

Pawczuk, L., Holdowsky, J., Masssey, R., & Hansen, B. (2020). Deloitte's 2020 Global Blockchain Survey: From promise to reality. *Deloitte Insights*. 1-44.

Rathore, M. M., Paul, A., & Ngai, E. W. (2021). Blockchain-based supply chain management: A comprehensive review. *International Journal of Information Management*, *56*, 102218.

Raut, R., Priyadarshinee, P., Jha, M., Gardas, B. B., & Kamble, S. (2018). Modeling the implementation barriers of cloud computing adoption: An interpretive structural modeling. *Benchmarking*, *25*(8), 2760–2782. https://doi.org/10.1108/BIJ-12-2016-0189

Rehouma, M. ben, & Hofmann, S. (2018). Government employees' adoption of information technology: A literature review. *Association for Computing Machinery, 43,* 1-10. https://doi.org/10.1145/3209281.3209311

Sánchez-Rodríguez, A., García-Alonso, J., Galán-Mena, J., & López-Coronado, M. (2021). Interoperability in blockchain-based supply chains: A systematic literature review. *Information Systems Frontiers*, 1-17.

Shieh, J. I., Wu, H. H., & Huang, K. K. (2010). A DEMATEL method in identifying key success factors of hospital service quality. *Knowledge-Based Systems*, *23*(3), 277–282. https://doi.org/10.1016/j.knosys.2010.01.013

Song, J., Zhang, P., Alkubati, M., Bao, Y., & Yu, G. (2021). Research advances on blockchain- as-a-service: architectures, applications and challenges. *Digital Communications and Networks*, *8*(4), 466-475. https://doi.org/10.1016/j.dcan.2021.02.001

Stern, E., Stame, N., Mayne, J., Forss, K., Davies, R., & Befani, B. (2012). *Broadening The Range of Designs and Methods for Impact Evaluations.*

Tapscott Don, & Tapscott Alex. (2016, May 10). *The Impact of the Blockchain Goes Beyond Financial Services*. https://hbr.org/2016/05/the-impact-of-the-blockchain-goes-beyond-financial-services

Tapscott, D., & Tapscott, A. (2016). *Blockchain revolution: how the technology behind bitcoin is changing money, business, and the world*. New York, NY. Portfolio Penguin.

Venkatesh, V. G., Kang, K., Wang, B., Zhong, R. Y., & Zhang, A. (2020). System architecture for blockchain based transparency of supply chain social sustainability. *Robotics and Computer-Integrated Manufacturing*, *63*, 101896. https://doi.org/10.1016/j.rcim.2019.101896

Vigna, P., & Casey, M. J. (2015). *The age of cryptocurrency: How bitcoin and digital money are challenging the global economic order*. New York, US. St. Martin's Publishing Group.

Wang, C., Wang, S., & Zhang, Y. (2020). Blockchain in supply chain management: Key applications and challenges in implementation. *International Journal of Production Research*, *58*(7), 2138-2158.

Wang, H., Xu, L. D., & Xu, E. (2021). Blockchain-based Internet of Things and its applications in supply chain management. *Journal of Industrial Information Integration, 22*, 100171.

Wang, Y., & Kogan, A. (2018). Designing confidentiality-preserving Blockchain-based transaction processing systems. *International Journal of Accounting Information Systems*, *30*, 1–18. https://doi.org/10.1016/j.accinf.2018.06.001

Wang, Y., Chen, C. H., & Zghari-Sales, A. (2021). Designing a blockchain enabled supply chain. *International Journal of Production Research*, *59*(5), 1450–1475. https://doi.org/10.1080/00207543.2020.1824086

World Economic Forum. (2018, April 23). *Blockchain beyond the hype: A practical framework for business leaders*. https://www.weforum.org/publications/blockchain-beyond-the-hype/

Yang, Y.-P. O., Shieh, H.-M., Leu, J.-D., & Tzeng, G.-H. (2008). A Novel Hybrid MCDM Model Combined with DEMATEL and ANP with Applications. *International Journal of Operations Research*, *5*(3).

Zafari, F., Gkelias, A., & Leung, K. (2017). A Survey of Indoor Localization Systems and Technologies. *IEEE Communications Surveys & Tutorials, 21*(3), 2568-2599. http://doi.org/10.1109/COMST.2019.2911558

Zeng, X., Lu, J., & Liu, S. (2019). The impact of information technology infrastructure flexibility on supply chain agility: An empirical study. *International Journal of Information Management*, *46*, 198-208.

Zhang, C., Chen, X., Guo, Y., & Jiang, H. (2020). Blockchain-based supply chain management: A comprehensive survey. *International Journal of Production Research*, *58*(17), 5173- 5193.

Zhang, G., Li, T., Li, Y., Hui, P., & Jin, D. (2018). Blockchain-Based Data Sharing System for AI-Powered Network Operations. *Journal of Communications and Information Networks*, *3*(3), 1–8. https://doi.org/10.1007/s41650-018-0024-3

Zhang, H., Wang, C., & Wang, S. (2021). Exploring the key determinants of blockchain technology adoption in supply chain management. *Journal of Cleaner Production*, *285*, 125315.

Zhang, X., Yang, J., & Liu, H. (2019). Blockchain technology in supply chain management: A review of applications, potentials, and challenges. *IEEE Transactions on Engineering Management*, *66*(4), 935-948.

Zhang, Y., Xu, L. D., Xu, E., & Wang, H. (2021). An intelligent supply chain management framework with blockchain and artificial intelligence. *International Journal of Production Research*, *59*(3), 795-815.

Zheng, Z., Xie, S., Dai, H., Chen, X., & Wang, H. (2017). An Overview of Blockchain Technology: Architecture, Consensus, and Future Trends. *IEEE, Big Data Congress 2017,* 557–564. https://doi.org/10.1109/BigDataCongress.2017.85

Zyskind, G., Nathan, O., & Pentland, A. S. (2015). Decentralizing privacy: Using blockchain to protect personal data. *IEEE Security and Privacy Workshops, SPW 2015,* 180–184. https://doi.org/10.1109/SPW.2015.27

Appendices

Appendix A

List of Enablers for Blockchain Architecture Adoption

Category	Factors	Sub-factors	Factor's Description	References
Technical Competencies	E1	Technical Literacy	The perceived specialised set of technical knowledge required as a necessity to operate the adopted technology.	Behnke & Janssen (2020) Mendling et al (2018)
	E2	Technical Expertise	The perceived specialised skillset required as a necessity to operate the adopted technology.	(S. Kamble et al., 2019)
	E3	Integral Education and Training	The imperative requirement of an organization to train and teach necessary knowledge and skills to operate the adopted technology effectively.	Kearns & Sabherwal (2006); Kleijnen et al (2009); Leimeister et al (2007)
	E4	Quality and Integrity	Attributed to the quality and integrity on the job's performance which utilizes technical knowledge and skillset.	(Tapscott Don & Tapscott Alex, 2016)
IT Infrastructure	E5	Technological Capabilities	The capabilities of the current technologypossessed by an organization to support the implementation venture of new technological system along with new process.	(Behnke & Janssen, 2020; Clohessy & Acton, 2019; Iansiti & Lakhani, 2017; Kaparthi & Bumblauskas, 2020; Ølnes et al., 2017; Öztürk & Yildizbaşi, 2020)
	E6	Financial Resources	The extent of an organization's ability to invest and risk the capital venture into the extent of implementing new technological infrastructure and facilities.	(Gökalp et al., 2022; Harrison et al., 2008; S. S. Kamble et al., 2020; Ølnes et al., 2017; Wang & Kogan, 2018)
	E7	Hardware and Software Compatibility	The compatible rate of hardware and software with the capabilities to implement, sustain and improve new technology.	Alkhater et al (2018); Clohessy & Acton (2019); Lai et al (2018); Rehouma & Hofmann (2018); Zafari et al (2017)
	E8	Cybersecurity and Resilience	The profound ability of cryptographic encrypted security keys to secure every transaction to maintain network privacy and protect against malicious activities.	Batubara et al (2018); Kshetri (2017); Mylrea et al (2017); Raut et al (2018); Zheng et al (2017)
	E9	Design Variables	The design variables involve the variables of technical components that are present in a technology such as Blockchain which allows customizable function for personalized use.	(Batubara et al., 2018)
	E10	Scalability	Refers to the ability of a system to scale and adapt with increased complex working principles and nature as technological requirements continues to escalate.	(Gökalp et al (2022); Koteska et al (2018); Öztürk & Yildizbaşi (2020); Wang & Kogan (2018)
Interoperability	E11	Rules and Standard	With multiple systems and perhaps multiple blockchain services might require rules and standard on how these different systems communicate and interact with each other.	Mendling et al (2018); Wang & Kogan (2018)
	E12	Adaptability	The perceptions of different technological systems to communicate and synchronize with each other.	Gordon & Catalini,2018; Tapscott Don & Tapscott Alex, 2016)
	E13	Increased Control	In the interoperability of the blockchain, increased control allows the manipulation of consensus mechanism to control transactions in the supply chain.	Kraft (2016); Mainelli & Smith (2015); Zyskind et al (2015)
	E14	Traceability	Traceability in blockchain technology allows absolute certainty and authenticity on the origin of the information sources.	Taudes & Tian (2018); Behnke & Janssen (2020; S. S. Kamble et al (2020)
	E15	Network Enhancement	The improvements of quality on all existing, internal, external, networks or even new network creation.	Hughes et al (2019); Kouhizadeh et al (2021); Narayanan et al (2016); Pawczuk et al (2020));
	E16	Verifiability of transactions	Every transactional activity among different technological system platform is verifiable which provides trail of transactions and non-repudiable.	Galal & Youssef (2018); Zhang et al (2018))
Compatibility	E17	Business Process Standardization	Standardization on the process of data transactions which includes the specifications and technical properties.	Bealt et al (2016); Kritchanchai et al (2018); Meng et al (2020)
	E18	Credible and Accurate Data	Any data that has been created would be verified and validated from reliable internal sources. Origin of data is ensured and added data into the blockchain is available for sharing and exchanges.	Behnke & Janssen (2020); Mendling et al (2018); Ølnes et al (2017); Wang et al

Category	Factors	Sub-factors	Factor's Description	References
				(2021)
	E19	Transparency and Auditability	Transparency is in the elaboration of granting visibility in each and every data transaction that has ever occurred in the past, present and forward in the future. This gives the ability for audit to create a trail within multiple ledgers for easier maneuverability and consistency in accessing transaction data,	Chod et al (2020); Hitaj et al (2017); Kshetri (2017); Lin (1999); Montecchi et al (2019); Venkatesh et al (2020); Zheng et al (2017)
	E20	Common rules on data disclosure	Constitute on data disclosure policy on categorized data for access in the blockchain and making it available for access among supply chain members.	Behnke & Janssen (2020); Wang et al (2021); Kouhizadeh et al (2021)
	E21	Common Objectives	Inaugurate cooperation and encouragement between supply chain members in supporting the ease of new technology implementation accommodate adoption and alignment on building a transparent culture.	Babich & Hilary (2019); Kouhizadeh et al (2021); Wang et al (2021)
	E22	Open to changes and adaptation	Common and mutual agreements among supply chain members would increase the chances of blockchain adoption and practice.	Behnke & Janssen (2020); Chang & Chen (2020); Gökalp et al (2022); Mendling et al (2018); Wang et al (2021)
Complexity	E23	New Technology Standard	Blockchain is still in its volatile state where standardization of data and interfaces with blockchain and different systems have not yet reached the significant stability.	Gökalp et al (2022); Lacity (2018); Ølnes et al (2017); Wang & Kogan (2018)
	E24	Application into SCM	New technological implementation into existing supply chain is challenging and difficult as it comprises of different complex intertwined levels of process and operations.	Clohessy & Acton (2019)
	E25	Rules and Governance	Requires an established clear and appropriate governance structure for decision-making and conflict resolution to create efficiencies.	Babich & Hilary (2019); Behnke & Janssen (2020); Gökalp et al (2022); Mendling et al (2018); Wang & Kogan (2018)
	E26	Complicated Tools and Equipment	Blockchain services comprises different sets of tools within different area of application and many of it are considered as specialized tools and equipment due to the dedicated design to certain specified platform and use case.	Öztürk & Yildizbaşi (2020)
	E27	Technological Volatility	Blockchain is a fairly new technology, and many uncertainties are revolving around the rate of changes in both specifications and improvements.	Martin et al (2020); Moezkarimi et al (2019)

Appendix	Elements	E1	E2	E3	E4	E5	E6	E7	E8	E9	E10	E11	E12	E13	E14	E15	E16	E17	E18	E19	E20	E21	E22	E23	E24	E25	E26	E27	
Direct Rela	E1	0	2.68	2.84	1.96	1.4	2.24	2.96	2.8	2.16	2.12	1.2	1.84	2.12	2.16	2.52	2.44	2.36	1.64	2.32	2.12	2.08	2.44	2.4	1.92	2.04	1.72	2.4	56.88
	E2	2.96	0	2.48	2.52	2.28	2.28	2.2	2.36	2.16	2.08	1.92	1.64	2.32	1.76	2.64	2	1.64	2.2	1.92	2.04	2.28	1.96	1.88	1.88	2.16	2.24	2.48	56.28
	E3	1.96	2.44	0	2.32	2.04	2.32	2.44	1.64	2.16	2.32	2.24	2	1.12	2	2.32	1.76	2.04	2.08	2.4	2.32	2.64	2.24	2.36	1.88	2	2.48	2.4	55.92
	E4	2.44	1.92	2.28	0	1.92	2.52	1.92	2.12	2.2	2.2	2.04	2	2.56	2.16	1.88	2.04	1.96	2.2	2.08	2.12	2.24	2.32	1.72	2.32	2.08	2.32	2.28	55.84
	E5	1.92	1.8	2.28	2.2	0	2.52	2.04	2.36	2.08	2.28	2.6	2	2.08	1.72	1.96	2.4	1.88	2.32	2.08	2.24	2	2.2	2.32	1.6	1.68	2.52	1.72	54.8
	E6	2.72	1.6	1.4	2.44	2.64	0	1.96	2.12	1.84	2.44	1.84	1.76	2.6	1.56	2.32	2.32	2.4	2.16	2.24	2.36	2.4	2.08	1.56	2.2	2.12	2.36	2.08	55.52
	E7	2.56	2.56	1.56	2.56	2.48	2.16	0	1.96	2.2	2.12	1.92	1.72	1.56	1.8	1.6	1.8	1.84	2	1.72	2.68	2.24	2.28	2.56	2.28	2.2	2.04	2.24	54.64
	E8	2.4	1.96	1.88	2.2	2.04	1.88	2.12	0	2.36	1.92	1.92	2	2.16	2.24	2.16	1.84	2.32	1.56	1.6	2.36	2.12	2.32	2.56	2.04	1.64	2.12	1.92	53.64
	E9	2.24	2.44	1.84	2.4	1.96	2.4	2.4	2.32	0	2.72	2.16	2.6	2.08	2.16	2.2	2.32	2	1.76	1.88	1.72	2.04	2.68	1.52	1.72	2	1.64	1.44	54.64
	E10	2.52	1.72	2.32	2.2	2.08	2.52	1.56	1.96	2.04	0	1.88	2.08	2.28	2.12	2.28	2.12	1.92	2.4	1.56	1.6	2.44	2	2.48	2	1.96	1.64	2.36	54.04
	E11	1.16	1.88	2.52	2.2	2.08	2	2	2.12	2.04	2.16	0	2.04	2.28	2.56	2	2.28	1.48	2.68	2.08	2.04	1.8	1.8	1.92	2.36	2.24	1.64	2.12	53.48
	E12	1.92	0.96	2	2.28	2.4	2.12	2.04	1.88	2.28	1.84	2.44	0	2.64	2.96	2.08	2.2	2.12	1.44	2.16	2.36	2.28	2	1.48	2.04	1.76	1.84	2.2	53.72
	E13	2.12	1.92	1.44	1.72	2.44	2.4	1.88	2.16	2.04	2	1.84	1.52	0	1.88	2.24	1.84	1.8	2.36	1.76	2.04	2.04	2.04	2.44	1.8	1.56	2.4	1.96	51.64
	E14	2.24	2.2	1.88	2.08	2.04	2.04	2	1.84	2.4	2.36	1.68	2.28	1.36	0	2.4	2	1.4	1.76	2	2.08	2.12	1.76	1.88	2.2	1.92	1.56	1.72	51.2
	E15	2.48	2.28	1.68	2.08	1.56	1.92	2.08	2.24	2.44	2.16	2.2	1.68	1.76	2.16	0	2.2	2	1.76	1.84	2.48	1.8	2.08	1.96	2.12	2.08	1.88	1.96	52.88
	E16	2.4	1.68	1.6	1.92	2.48	1.96	2.64	1.8	1.96	2	2.04	1.76	2.04	2.52	1.88	0	2.04	1.96	2.68	2.44	2.04	1.92	2.24	2.12	2.24	2.16	1.68	54.2
	E17	1.64	2.28	2.28	1.72	2.28	1.68	2.24	2.36	1.92	2.2	1.88	2	2.4	1.64	2.28	2	0	1.96	1.8	1.72	2.24	2.44	2.28	1.72	2.16	2.16	2.16	53.44
	E18	1.84	1.56	2.12	2.04	2.24	2.52	2	1.84	2.2	1.76	1.8	1.36	1.52	2	1.56	2.44	1.72	0	2.12	2.36	1.92	2.16	2.2	1.56	1.64	2.04	1.84	50.36
	E19	2.24	1.72	1.76	1.76	1.88	1.84	2	1.84	1.76	2.12	2.84	2.08	1.56	1.72	2.04	2.4	2.12	1.52	0	1.88	1.96	1.96	1.76	1.48	1.76	2.12	2.12	50.24
	E20	1.96	2.32	2.36	2.04	2.2	1.92	2.6	2.08	2.36	1.6	1.92	1.64	2.24	1.48	2.4	2.68	1.48	1.68	1.92	0	1.72	2.16	2.24	1.64	1.92	2.24	1.96	52.76
	E21	2.6	1.56	2.12	2.2	2.28	2.24	2.44	1.68	2.28	2.2	2.16	1.92	2.28	2.32	1.92	1.32	2.2	1.68	1.84	1.88	0	2.4	1.96	2.12	1.56	2.04	2.08	53.28
	E22	2.2	1.84	1.84	1.84	2.48	1.88	1.92	1.96	1.88	1.8	2	1.8	1.88	1.68	1.92	1.36	1.6	1.96	1.84	1.88	1.72	0	2.76	2	2.16	1.88	1.68	49.76
	E23	1.52	2.52	2.28	1.88	2.16	2.08	1.88	2.28	1.96	1.76	1.92	1.8	1.68	1.64	2.08	1.84	2.28	2.08	1.36	2.12	2.48	1.88	0	2.72	2.36	2.48	2	53.04
	E24	2	1.8	1.8	1.84	2.08	2.52	2.92	2.24	1.8	2.08	2.4	2.28	2.16	1.52	2.44	2.32	2.04	2.48	1.96	1.52	2	1.92	2	0	2.12	1.68	1.92	53.84
	E25	1.88	2.36	2.32	1.92	2	1.76	1.92	2.68	2.2	2.24	1.92	1.6	2.44	2.32	2	1.64	1.96	1.92	2.08	2.12	2.2	2.12	2.12	1.76	0	2.28	1.92	53.68
	E26	1.8	2.08	2.04	1.96	1.68	2.16	2.2	1.8	2.16	2.12	2.6	2.32	1.88	2.24	2.08	2.48	2.24	1.8	2	2.24	2.24	2.08	1.72	2.64	1.68	0	1.56	53.8
	E27	2.24	2.04	2.28	1.76	2.24	2.08	2.04	2.36	2.16	2.4	2.16	2.08	1.76	2.44	2.28	1.84	2.4	2.2	2.36	1.8	2.44	2.76	2.2	1.92	1.96	1.44	0	55.64
		55.96	52.12	53.2	54.04	55.36	55.96	56.4	54.8	55.04	55	53.52	49.8	52.76	52.76	55.48	53.88	51.24	51.56	51.6	54.52	55.48	56	54.52	52.04	51	52.92	52.2	

Appendix	Elements	E1	E2	E3	E4	E5	E6	E7	E8	E9	E10	E11	E12	E13	E14	E15	E16	E17	E18	E19	E20	E21	E22	E23	E24	E25	E26	E27
Normalize	E1	0	0.04712	0.04993	0.03446	0.02461	0.03938	0.05204	0.04923	0.03797	0.03727	0.0211	0.03235	0.03727	0.03797	0.0443	0.0429	0.04149	0.02883	0.04079	0.03727	0.03657	0.0429	0.04219	0.03376	0.03586	0.03024	0.04219
	E2	0.05204	0	0.0436	0.0443	0.04008	0.04008	0.03868	0.04149	0.03797	0.03657	0.03376	0.02883	0.04079	0.03094	0.04641	0.03516	0.02883	0.03868	0.03376	0.03586	0.04008	0.03446	0.03305	0.03305	0.03797	0.03938	0.0436
	E3	0.03446	0.0429	0	0.04079	0.03586	0.04079	0.0429	0.02883	0.03797	0.04079	0.03938	0.03516	0.01969	0.03516	0.04079	0.03094	0.03586	0.03657	0.04219	0.04079	0.04641	0.03938	0.04149	0.03305	0.03516	0.0436	0.04219
	E4	0.0429	0.03376	0.04008	0	0.03376	0.0443	0.03376	0.03727	0.03868	0.03868	0.03586	0.03516	0.04501	0.03797	0.03305	0.03586	0.03446	0.03868	0.03657	0.03727	0.03938	0.04079	0.03024	0.04079	0.03657	0.04079	0.04008
	E5	0.03376	0.03165	0.04008	0.03868	0	0.0443	0.03586	0.04149	0.03657	0.04008	0.04571	0.03516	0.03657	0.03024	0.03446	0.04219	0.03305	0.04079	0.03657	0.03938	0.03516	0.03868	0.04079	0.02813	0.02954	0.0443	0.03024
	E6	0.04782	0.02813	0.02461	0.0429	0.04641	0	0.03446	0.03727	0.03235	0.0429	0.03235	0.03094	0.04571	0.02743	0.04079	0.04079	0.04219	0.03797	0.03938	0.04149	0.04219	0.03657	0.02743	0.03868	0.03727	0.04149	0.03657
	E7	0.04501	0.04501	0.02743	0.04501	0.0436	0.03797	0	0.03446	0.03868	0.03727	0.03376	0.03024	0.02743	0.03165	0.02813	0.03165	0.03235	0.03516	0.03024	0.04712	0.03938	0.04008	0.04501	0.04008	0.03868	0.03586	0.03938
	E8	0.04219	0.03446	0.03305	0.03868	0.03586	0.03305	0.03727	0	0.04149	0.03376	0.03376	0.03516	0.03797	0.03938	0.03797	0.03235	0.04079	0.02743	0.02813	0.04149	0.03727	0.04079	0.04501	0.03586	0.02883	0.03727	0.03376
	E9	0.03938	0.0429	0.03235	0.04219	0.03446	0.04219	0.04219	0.04079	0	0.04782	0.03797	0.04571	0.03657	0.03797	0.03868	0.04079	0.03516	0.03094	0.03305	0.03024	0.03586	0.04712	0.02672	0.03024	0.03516	0.02883	0.02532
	E10	0.0443	0.03024	0.04079	0.03868	0.03657	0.0443	0.02743	0.03446	0.03586	0	0.03305	0.03657	0.04008	0.03727	0.04008	0.03727	0.03376	0.04219	0.02743	0.02813	0.0429	0.03516	0.0436	0.03516	0.03446	0.02883	0.04149
	E11	0.02039	0.03305	0.0443	0.03868	0.03657	0.03516	0.03516	0.03727	0.03586	0.03797	0	0.03586	0.04008	0.04501	0.03516	0.04008	0.02602	0.04712	0.03657	0.03586	0.03165	0.03165	0.03376	0.04149	0.03938	0.02883	0.03727
	E12	0.03376	0.01688	0.03516	0.04008	0.04219	0.03727	0.03586	0.03305	0.04008	0.03235	0.0429	0	0.04641	0.05204	0.03657	0.03868	0.03727	0.02532	0.03797	0.04149	0.04008	0.03516	0.02602	0.03586	0.03094	0.03235	0.03868
	E13	0.03727	0.03376	0.02532	0.03024	0.0429	0.04219	0.03305	0.03797	0.03586	0.03516	0.03235	0.02672	0	0.03305	0.03938	0.03235	0.03165	0.04149	0.03094	0.03586	0.03586	0.03586	0.0429	0.03165	0.02743	0.04219	0.03446
	E14	0.03938	0.03868	0.03305	0.03657	0.03586	0.03586	0.03516	0.03235	0.04219	0.04149	0.02954	0.04008	0.02391	0	0.04219	0.03516	0.02461	0.03094	0.03516	0.03657	0.03727	0.03094	0.03305	0.03868	0.03376	0.02743	0.03024
	E15	0.0436	0.04008	0.02954	0.03657	0.02743	0.03376	0.03657	0.03938	0.0429	0.03797	0.03868	0.02954	0.03094	0.03797	0	0.03868	0.03516	0.03094	0.03235	0.0436	0.03165	0.03657	0.03446	0.03727	0.03657	0.03305	0.03446
	E16	0.04219	0.02954	0.02813	0.03376	0.0436	0.03446	0.04641	0.03165	0.03446	0.03516	0.03586	0.03094	0.03586	0.0443	0.03305	0	0.03586	0.03446	0.04712	0.0429	0.03586	0.03376	0.03938	0.03727	0.03938	0.03797	0.02954
	E17	0.02883	0.04008	0.04008	0.03024	0.04008	0.02954	0.03938	0.04149	0.03376	0.03868	0.03305	0.03516	0.04219	0.02883	0.04008	0.03516	0	0.03446	0.03165	0.03024	0.03938	0.0429	0.04008	0.03024	0.03797	0.03797	0.03797
	E18	0.03235	0.02743	0.03727	0.03586	0.03938	0.0443	0.03516	0.03235	0.03868	0.03094	0.03165	0.02391	0.02672	0.03516	0.02743	0.0429	0.03024	0	0.03727	0.04149	0.03376	0.03797	0.03868	0.02743	0.02883	0.03586	0.03235
	E19	0.03938	0.03024	0.03094	0.03094	0.03305	0.03235	0.03516	0.03235	0.03094	0.03727	0.04993	0.03657	0.02743	0.03024	0.03586	0.04219	0.03727	0.02672	0	0.03305	0.03446	0.03446	0.03094	0.02602	0.03094	0.03727	0.03727
	E20	0.03446	0.04079	0.04149	0.03586	0.03868	0.03376	0.04571	0.03657	0.04149	0.02813	0.03376	0.02883	0.03938	0.02602	0.04219	0.04712	0.02602	0.02954	0.03376	0	0.03024	0.03797	0.03938	0.02883	0.03376	0.03938	0.03446
	E21	0.04571	0.02743	0.03727	0.03868	0.04008	0.03938	0.0429	0.02954	0.04008	0.03868	0.03797	0.03376	0.04008	0.04079	0.03376	0.02321	0.03868	0.02954	0.03235	0.03305	0	0.04219	0.03446	0.03727	0.02743	0.03586	0.03657
	E22	0.03868	0.03235	0.03235	0.03235	0.0436	0.03305	0.03376	0.03446	0.03305	0.03165	0.03516	0.03165	0.03305	0.02954	0.03376	0.02391	0.02813	0.03446	0.03235	0.03305	0.03024	0	0.04852	0.03516	0.03797	0.03305	0.02954
	E23	0.02672	0.0443	0.04008	0.03305	0.03797	0.03657	0.03305	0.04008	0.03446	0.03094	0.03376	0.03165	0.02954	0.02883	0.03657	0.03235	0.04008	0.03657	0.02391	0.03727	0.0436	0.03305	0	0.04782	0.04149	0.0436	0.03516
	E24	0.03516	0.03165	0.03165	0.03235	0.03657	0.0443	0.05134	0.03938	0.03165	0.03657	0.04219	0.04008	0.03797	0.02672	0.0429	0.04079	0.03586	0.0436	0.03446	0.02672	0.03516	0.03376	0.03516	0	0.03727	0.02954	0.03376
	E25	0.03305	0.04149	0.04079	0.03376	0.03516	0.03094	0.03376	0.04712	0.03868	0.03938	0.03376	0.02813	0.0429	0.04079	0.03516	0.02883	0.03446	0.03376	0.03657	0.03727	0.03868	0.03727	0.03727	0.03094	0	0.04008	0.03376
	E26	0.03165	0.03657	0.03586	0.03446	0.02954	0.03797	0.03868	0.03165	0.03797	0.03727	0.04571	0.04079	0.03305	0.03938	0.03657	0.0436	0.03938	0.03165	0.03516	0.03938	0.03938	0.03657	0.03024	0.04641	0.02954	0	0.02743
	E27	0.03938	0.03586	0.04008	0.03094	0.03938	0.03657	0.03586	0.04149	0.03797	0.04219	0.03797	0.03657	0.03094	0.0429	0.04008	0.03235	0.04219	0.03868	0.04149	0.03165	0.0429	0.04852	0.03868	0.03376	0.03446	0.02532	0

Appendix	Elements	E1	E2	E3	E4	E5	E6	E7	E8	E9	E10	E11	E12	E13	E14	E15	E16	E17	E18	E19	E20	E21	E22	E23	E24	E25	E26	E27	Sum C
Total Rela	E1	0.65	0.652	0.664	0.661	0.665	0.686	0.703	0.682	0.675	0.673	0.641	0.61	0.648	0.648	0.685	0.665	0.635	0.627	0.638	0.669	0.678	0.69	0.674	0.638	0.628	0.644	0.647	17.774
	E2	0.693	0.601	0.653	0.664	0.674	0.681	0.685	0.67	0.669	0.667	0.647	0.602	0.646	0.636	0.681	0.653	0.618	0.631	0.626	0.662	0.675	0.677	0.659	0.631	0.624	0.647	0.642	17.613
	E3	0.672	0.637	0.607	0.656	0.665	0.677	0.684	0.653	0.664	0.666	0.648	0.604	0.622	0.635	0.671	0.644	0.62	0.624	0.629	0.661	0.676	0.676	0.662	0.627	0.617	0.646	0.636	17.481
	E4	0.679	0.628	0.644	0.616	0.662	0.679	0.674	0.659	0.663	0.663	0.643	0.602	0.644	0.637	0.663	0.648	0.618	0.625	0.623	0.657	0.668	0.676	0.651	0.633	0.617	0.642	0.633	17.445
	E5	0.658	0.615	0.633	0.642	0.618	0.667	0.664	0.652	0.65	0.653	0.641	0.592	0.625	0.619	0.652	0.642	0.606	0.616	0.612	0.647	0.653	0.662	0.649	0.611	0.6	0.634	0.613	17.127
	E6	0.68	0.619	0.626	0.653	0.67	0.633	0.671	0.656	0.654	0.663	0.636	0.595	0.642	0.623	0.666	0.649	0.622	0.621	0.622	0.657	0.667	0.669	0.645	0.627	0.614	0.639	0.627	17.347
	E7	0.668	0.627	0.621	0.647	0.659	0.661	0.629	0.645	0.651	0.65	0.629	0.587	0.616	0.619	0.646	0.632	0.605	0.611	0.606	0.654	0.656	0.663	0.653	0.621	0.608	0.626	0.621	17.112
	E8	0.654	0.606	0.615	0.63	0.64	0.644	0.653	0.6	0.642	0.635	0.618	0.581	0.615	0.615	0.644	0.621	0.602	0.592	0.593	0.637	0.643	0.652	0.641	0.606	0.588	0.616	0.605	16.788
	E9	0.663	0.624	0.624	0.644	0.65	0.664	0.668	0.65	0.613	0.659	0.632	0.6	0.624	0.625	0.655	0.639	0.606	0.606	0.608	0.638	0.652	0.669	0.635	0.611	0.604	0.619	0.607	17.089
	E10	0.66	0.606	0.626	0.634	0.645	0.66	0.648	0.638	0.642	0.607	0.622	0.586	0.621	0.618	0.65	0.63	0.6	0.611	0.597	0.629	0.653	0.652	0.644	0.61	0.598	0.613	0.616	16.915
	E11	0.631	0.602	0.622	0.627	0.638	0.644	0.648	0.633	0.634	0.636	0.583	0.579	0.614	0.618	0.638	0.626	0.585	0.608	0.598	0.629	0.635	0.641	0.628	0.608	0.595	0.606	0.605	16.711
	E12	0.646	0.589	0.616	0.631	0.646	0.648	0.652	0.632	0.641	0.634	0.627	0.547	0.623	0.627	0.642	0.627	0.598	0.59	0.602	0.637	0.645	0.647	0.623	0.606	0.59	0.611	0.609	16.786
	E13	0.627	0.584	0.586	0.6	0.624	0.63	0.626	0.615	0.615	0.614	0.595	0.553	0.557	0.588	0.622	0.6	0.572	0.585	0.575	0.61	0.619	0.625	0.617	0.581	0.566	0.599	0.584	16.17
	E14	0.625	0.585	0.59	0.603	0.614	0.621	0.625	0.606	0.617	0.616	0.589	0.562	0.577	0.553	0.621	0.599	0.562	0.571	0.575	0.607	0.617	0.617	0.604	0.584	0.569	0.582	0.577	16.066
	E15	0.647	0.604	0.604	0.62	0.624	0.637	0.644	0.63	0.636	0.631	0.615	0.568	0.601	0.606	0.599	0.619	0.589	0.588	0.589	0.631	0.629	0.64	0.623	0.6	0.588	0.604	0.598	16.564
	E16	0.659	0.606	0.615	0.63	0.653	0.651	0.667	0.636	0.641	0.641	0.625	0.582	0.618	0.625	0.644	0.595	0.602	0.604	0.615	0.644	0.646	0.651	0.641	0.612	0.603	0.622	0.606	16.931
	E17	0.639	0.609	0.619	0.619	0.642	0.638	0.652	0.637	0.633	0.637	0.615	0.578	0.616	0.603	0.643	0.621	0.56	0.597	0.593	0.624	0.642	0.651	0.634	0.598	0.594	0.614	0.606	16.715
	E18	0.608	0.565	0.584	0.592	0.608	0.618	0.614	0.595	0.604	0.596	0.581	0.538	0.57	0.577	0.597	0.596	0.558	0.532	0.568	0.602	0.603	0.613	0.6	0.564	0.555	0.58	0.569	15.789
	E19	0.614	0.567	0.577	0.586	0.601	0.606	0.613	0.595	0.596	0.601	0.598	0.549	0.57	0.572	0.604	0.594	0.564	0.557	0.531	0.593	0.603	0.609	0.591	0.562	0.556	0.58	0.573	15.764
	E20	0.638	0.604	0.614	0.618	0.634	0.636	0.652	0.626	0.633	0.621	0.609	0.567	0.607	0.594	0.638	0.626	0.579	0.586	0.59	0.589	0.627	0.64	0.627	0.591	0.584	0.61	0.597	16.536
	E21	0.653	0.596	0.615	0.626	0.64	0.647	0.654	0.625	0.637	0.636	0.618	0.576	0.613	0.613	0.636	0.609	0.596	0.591	0.593	0.625	0.603	0.65	0.627	0.604	0.583	0.611	0.604	16.681
	E22	0.607	0.564	0.573	0.582	0.605	0.602	0.606	0.591	0.592	0.591	0.578	0.539	0.57	0.565	0.597	0.572	0.55	0.559	0.557	0.587	0.594	0.57	0.602	0.565	0.557	0.572	0.561	15.61
	E23	0.633	0.609	0.615	0.619	0.636	0.642	0.643	0.633	0.63	0.626	0.612	0.572	0.601	0.6	0.636	0.615	0.595	0.595	0.583	0.627	0.643	0.639	0.592	0.612	0.594	0.616	0.6	16.62
	E24	0.649	0.605	0.615	0.626	0.643	0.657	0.668	0.64	0.635	0.639	0.628	0.587	0.617	0.606	0.65	0.631	0.599	0.609	0.601	0.626	0.643	0.648	0.634	0.573	0.598	0.611	0.607	16.842
	E25	0.645	0.613	0.622	0.625	0.639	0.642	0.649	0.645	0.64	0.64	0.618	0.574	0.619	0.616	0.641	0.618	0.596	0.598	0.6	0.633	0.644	0.649	0.634	0.601	0.56	0.619	0.605	16.784
	E26	0.645	0.609	0.618	0.627	0.636	0.65	0.656	0.632	0.64	0.639	0.631	0.587	0.612	0.617	0.643	0.633	0.601	0.598	0.601	0.636	0.646	0.649	0.628	0.617	0.59	0.581	0.6	16.825
	E27	0.672	0.627	0.641	0.643	0.664	0.669	0.673	0.66	0.66	0.663	0.642	0.601	0.628	0.638	0.666	0.641	0.622	0.622	0.625	0.648	0.669	0.68	0.656	0.623	0.613	0.625	0.592	17.364
	Sum R	17.515	16.352	16.639	16.922	17.296	17.489	17.62	17.134	17.206	17.197	16.722	15.619	16.512	16.493	17.33	16.846	16.062	16.155	16.15	17.06	17.328	17.505	17.074	16.318	15.994	16.567	16.342	