Assessing the Ceramic Industry for Sustainable Supply Chain Management in Bangladesh: An Insight Using the Fuzzy DEMATEL Method

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CERTIFICATE OF RESEARCH

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DECLARATION

*I hereby declare that this thesis entitled **“Development of a Predictive Model to Select Material for Motorcyclists' Impact Protector Design”** is an authentic report of* a *study carried out as a requirement for the award of degree B.Sc. (Industrial and Production Engineering) at Islamic University of Technology, Gazipur, Dhaka, under the supervision of Dr. A. R. M. Harunur Rashid, Professor, MPE, IUT in the year 2024*

The matter embodied in this thesis has not been submitted in part or full to any other institute for the *award of any degree.*

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ABSTRACT

This study looks closely at Bangladesh's ceramic industry's sustainable supply chain management. It analyzes the intricate cause-and-effect relationships that affect sustainability using the Fuzzy Decision Making Trial and Evaluation Laboratory (DEMATEL) technique. The ceramic industry, which is vital to Bangladesh's economy, is currently facing significant environmental challenges, including high greenhouse gas emissions, resource depletion, and waste management challenges. These environmental issues highlight how urgently a systematic approach to sustainability is required.

The study identifies important causal factors that have a major impact on the dynamics of the industry's supply chain, such as Supplier Partnership Development, Collaborative Sustainable Initiatives, and Sustainable Industry Resilience. Conversely, the effects under investigation—Cost Optimization, Greenhouse Gas Emissions Assessment, and Competitive Edge in the Market—showcase the industry's present state of sustainability as well as its room for improvement. The study highlights complex relationships across the supply chain, initially based on the perspective of a single expert. For industry participants looking to reconcile environmental stewardship with economic growth, it offers insightful information.

The research proposes to use Flexsim simulation tools in the future to validate and enhance our theoretical findings. This method provides practical, scenario-driven insights that are critical for successfully putting sustainable principles into practice. Future versions of the study will include a wider spectrum of expert opinions to solve the disadvantage of relying only on one expert perspective, ensuring a more thorough and accurate analysis.

This work serves as both an important guide for Bangladesh's ceramic industry and a significant addition to the understanding of sustainable supply chain management in poor nations. It provides a way to mitigate environmental impacts while maintaining economic viability, making it an essential component of the global movement toward sustainable industrial practices.

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NOMENCLATURE

HI	High Influence
LI	Low Influence
NI	No Influence
VH	Very High Influence
VL	Very Low Influence
TFN	True Fuzzy Numbers
LCA	Life Cycle Analysis

CHAPTER 01: INTRODUCTION

The ceramics industry, which is widely recognized for its economic significance, is essential to the manufacturing sector. However, the industry's environmental impact is becoming a growing source of worry, especially in nations like Bangladesh where it is expanding rapidly. The manufacturing methods for ceramics are known for consuming a lot of resources, such as electricity and water, and for producing a variety of pollutants. For instance, it has been shown that the ceramic industry contributes significantly to climate change by producing large amounts of CO2. Bangladesh's ceramic sector has grown quickly in recent years, becoming a major player in both the local and international markets. Although there is no denying the expansion's economic benefits, there are serious questions about how long-term the environmental sustainability is raised.

Globally, the ceramics sector has a large impact on the environment. The production of ceramics can emit up to 0.13 kg of CO2 per kilogram of output and consume up to 50 MJ/kg of energy, according to Ros-Dosdá et al. (2018). Depending on the kind of production techniques used and how effective they are, the precise amounts may change. Furthermore, hazardous substances and toxic heavy metals are commonly found in the waste generated during the production of ceramics, posing serious risks to ecosystems and human health [(Quinteiro et al., 2012)].

In this specific case, the concept of a sustainable supply chain is becoming increasingly relevant. In the ceramic industry, creating a sustainable supply chain means managing the negative effects on the environment, society, and economy at every point in the lifecycle of ceramic products. This approach has the potential to mitigate the environmental consequences of manufacturing, promote resource conservation, and ensure the well-being of communities affected by industrial activities. A significant shift toward more ethical production practices would be necessary for Bangladesh to adopt sustainable supply chain strategies. This is especially important in light of the nation's aggressive goals for economic expansion and its vulnerability to climate change.

In this case, the Fuzzy Decision Making Trial and Evaluation Laboratory (DEMATEL) method is an effective tool. In complex and linked problem situations, like those seen in supply chain management, fuzzy logic—a system that takes uncertainties and subjective judgments into account—is extremely helpful (Govindan et al., 2015; Ye et al., 2018). The utilization of Fuzzy DEMATEL makes it easier to recognize and decipher complex causal relationships between various system components. It can clarify the intricate interactions between several supply chain elements and how they affect sustainability in the ceramics industry.

We employ the Fuzzy DEMATEL method to examine and make sense of the many intricate aspects of Bangladesh's ceramic industry. Finding key leverage areas and strategies that can significantly increase the supply chain's sustainability is our goal. This approach focuses on creating a strong, efficient, and socially responsible supply chain in addition to minimizing the negative effects on the environment. By providing well-informed guidance to industry participants, environmental organizations, and legislators, the insights obtained from this strategy can ultimately steer the ceramic industry towards a more sustainable path.

In subsequent research, we want to use the Life Cycle Analysis (LCA) method to further validate our findings. Using this method will enable us to evaluate the supply chain of the ceramic industry's environmental effects in its entirety, from the extraction of raw materials to the disposal of end-of-life products. By incorporating LCA, we hope to measure the advantages of our suggested sustainable practices, offering a strong foundation for ongoing development and proving the industry's long-term feasibility of sustainable supply chain management.

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CHAPTER 02: LITERATURE REVIEW

The global push for sustainability has had a significant impact on the ceramics industry. Bangladesh's ceramic sector is crucial to the country's economy because it exports to both the domestic market and other countries. However, this industry finds it challenging to align its supply chain management tactics with the goals of sustainable development. This review of the literature looks at the body of knowledge currently available on sustainable supply chain management (SSCM) with a focus on Bangladesh's ceramic industry. This study is important because it provides insightful information about the unique challenges and opportunities related to sustainability in Bangladesh's ceramic industry. Bangladesh is a particularly relevant topic to focus on because of its growing industrial sector and the global focus on sustainable practices. Acquiring knowledge about the possibility of the ceramic industry shifting to more environmentally friendly methods is crucial to guaranteeing long-term social, economic, and environmental sustainability. The study will commence with a synopsis of sustainable supply chain management, emphasizing its importance and use in many industries around the globe, including Bangladesh. The ceramic sector in Bangladesh will then be thoroughly examined, including its current practices, challenges, and opportunities for incorporating sustainable approaches. The Fuzzy DEMATEL technique will be examined in the next section, where its principles, applications in the past, and importance in assessing SSCM will all be elucidated. The assessment will conclude by looking at how the Fuzzy DEMATEL approach can offer new perspectives and solutions for the long-term development of Bangladesh's ceramic industry.

The fuzzy DEMATEL approach was expanded to the approximation fuzzy Decision Making Trial and Evaluation Laboratory (AFDEMA-TEL) method by Lin et al. (2018) in order to obtain a thorough grasp of the application of fuzzy DEMATEL in the Sustainable Supply Chain. This improvement improves how fuzzy cause-and-effect interactions are handled in ambiguous situations. The AFDEMATEL method produces more consistent results and is able to identify differences in the cross-different quadrants phenomenon's occurrence at various levels. To evaluate the efficacy of sustainable supply chain management, the AFDEMATEL technique uses approximate fuzzy arithmetic operations with the weakest t-norm arithmetic operations. It accurately assesses ambiguous influential elements and provides reliable fuzzy cause and effect correlations. There are no explicit limitations or limits mentioned in the study.

However, it is imperative to recognize that the outcomes and conclusions drawn from the methodology depend on the information collected and the specific standards used for evaluation. The specific dimensions and criteria outlined in the research may limit the findings' applicability.

According to Kristanto et al. (2012), implementing an adaptive fuzzy control application that supports vendor-managed inventory (VMI) is one way to lessen the bullwhip impact in the supply chain. The main contribution of this method is the introduction of the idea of adaptive fuzzy VMI control. The Bullwhip impact in supply networks is the primary focus of this research. The effectiveness of adaptive fuzzy VMI control is compared to fuzzy VMI control and traditional VMI through a comparative analysis. The results show that the adaptive fuzzy VMI control outperforms the other two methods in terms of reducing backorders, decreasing delivery overshoots, and effectively mitigating the Bullwhip effect. The study focuses on the technical challenges of improving demand information accuracy by looking at a variety of variables, such as demand fluctuations, prediction error, and inventory availability. By applying the proposed adaptive fuzzy VMI control, the authors conduct a thorough analysis and comparison of two vendor-managed inventory (VMI) models. The GoldSim simulation program is used to show a numerical example and assess the supply chain's response in relation to various parameters. Over a period of 1000 days, the simulation is run with different amounts of demand and inventory. The ANOVA test is utilized to determine whether the Houlihan and Burbidge effects are present. The efficacy of the fuzzy VMI control is evaluated in comparison to conventional and GA-based fuzzy VMI control systems, and the Bullwhip effect is measured. The paper does not, however, address any potential drawbacks or compromises that can result from using a fuzzy control method in the context of supply chain management and VMI.

According to Mohammed and Wang (2017), the goal of creating the product distribution planner is to build a three-tiered green meat supply chain (MSC) that considers the environmental impact as a new factor. To cut down on CO2 emissions during transportation, shorten product distribution times, minimize overall transportation and implementation costs, and increase average delivery rates, a fuzzy multi-objective programming model (FMOPM) is created. To optimize all four objectives simultaneously, three different solution strategies were investigated and used: the LP-metrics method, the ε-constraint method, and the goal programming method. By comparing the Pareto solutions identified, the optimal answer is found using the Max-Min technique. Regarding the constraints or limitations of the several solution approaches—such as the goal programming technique, ε-constraint method, and LP-metrics method—no information is provided in the paper. The limitations and factors to be taken into account when applying or extrapolating the developed model to different supply chain networks or industries are not included in the study.

(Wang & Shu, 2005) presented a fuzzy supply chain model that uses possibility theory to evaluate supply chain performance in order to resolve uncertainties and establish inventory strategies in supply chain management. Furthermore, the best order-up-to levels for stock-keeping units (SKUs) in the supply chain are found using a genetic algorithm approach. Reducing inventory expenses while maintaining the targeted fill rate for the final product is the goal. Improved supply chain inventory strategies are the outcome of decision-makers being able to express their risk preferences and assess how best to balance inventory investment and customer service level in the supply chain thanks to the developed model. Decision-makers are able to express their risk preferences and analyze the trade-off between inventory investment and customer service level in the SC by using the proposed fuzzy supply chain (SC) model. The limitations of the fuzzy choice methodology and genetic algorithm approach used to create inventory strategies in supply chain management are not well examined in this research. The paper does not address potential challenges or limitations related to using possibility distributions and fuzzy set theory to represent uncertain supply chain factors. The limitations or drawbacks that could arise from using six-point fuzzy numbers for computing efficiency and approximation are not discussed in the research.

In order to ascertain the elements of corporate culture that impact corporate sustainability performance, a hierarchical evaluation methodology has been established by Islam et al. (2019). This approach makes it possible to assess how well a company performs in terms of sustainability using its corporate culture. ranks and prioritizes aspects by converting qualitative, subjective human perceptions into quantitative data via fuzzy synthetic evaluation (FSE). The study utilized the DEMATEL technique to examine the interdependencies between attributes within a hierarchical framework. A hierarchical measuring framework was employed in the study to evaluate the attributes of business sustainability performance. Fuzzy set theory and

DEMATEL are combined in the FSE-DEMATEL approach to address the ambiguity of human perception and the interdependence of attributes. The lack of a clear explanation of the study's limits in the report makes it difficult to understand any possible flaws or restrictions in the research methodology or findings. The sources that are provided do not delve into the particular limitations related to the use of the FSE-DEMATEL methodology and the hierarchical evaluation structure. If the study's focus is on a specific sector or setting, then the findings' generalizability can be limited.

In Çelik & Arslankaya's (2023) analysis of the quality control standards in the glass sector, the fuzzy DEMATEL method—a multi-criteria decision-making tool—is recommended. The study was conducted in a factory that makes tempered glass. The processed glasses are returned to the company once contract manufacturing is finished, where they undergo quality control tests before being tempered and shipped ready. During the quality control process, a number of control criteria were considered, such as aspect measurement, optical image control, bubble control, scratch control, lapping type control, hole diameter control, and flaking control. A fuzzy total relationship matrix was used to illustrate the interrelationships between the criteria, and specific formulas were applied to establish the weights of the criterion. The possible impact of outside variables on the stated quality control standards, such as market demand or technological advancements, is not discussed in the paper.

In order to assess the degree of impact that various factors have on the adoption of Green Lean Supply Chain Management (GLSCM) in Bangladeshi industries, Hossain et al. (2023) propose the use of the Fuzzy Decision-Making Trial and Evaluation Laboratory (Fuzzy DEMATEL) method. The research highlights that the most important components of Green Logistics and Supply Chain Management (GLSCM) are capacity utilization, green purchasing, and demand volatility; quality improvement and the Kanban system are viewed as the least important components. The study used in this paper is based on the Fuzzy DEMATEL approach, which comprises creating a questionnaire using linguistic ideas and conversing with domain experts to gather their opinions on the importance of the items under consideration. Cronbach's alpha coefficient is used to evaluate the reliability of the elements that have been found, and a response rate of 60% is deemed sufficient for investigation. The study also makes use of visual aids to help understand the components that are prioritized and how they relate to each other, such as causal diagrams and factor rankings. The study recognizes a number of limitations that need to be considered. Because of possible differences in components and how important they are in other industries or regions, the results may not be as generalizable to other sectors or areas. Moreover, the Fuzzy DEMATEL method relies on subjective assessments and expert opinions, which may add biases of its own and increase outcome unpredictability. Furthermore, the quality and accessibility of the data used in the study may have an impact on the reliability and accuracy of the findings. Furthermore, the study does not take into consideration the dynamic nature of markets and industries, since evolving technology, market trends, or regulatory frameworks may cause the defined criteria and their relative importance to alter over time. It is advised to incorporate sub-criteria into the analysis, consider the influence of external factors on the identified factors and their ranking, and develop decision support systems or tools based on the study's findings to help managers effectively implement lean and green supply chain management strategies in order to get around these limitations and improve future research.

Bathaei et al. (2021) suggest using the fuzzy direct relation matrix and fuzzy total correlation matrix to evaluate the criteria in order to gain an edge in the supplier selection process. This method makes it possible to thoroughly examine the relationships between different criteria. The process for obtaining the exact total correlation matrix is described in the article. It entails transforming the fuzzy correlation matrix into a crisp form, adding up the rows and columns, building an Ali-Disabled Chart, and making a network map. The use of additional approaches, such as fuzzy DEMATEL, fuzzy VICOR, and fuzzy DANP, is also covered in the text. The paper provides a comprehensive analysis of resilience, supply chain management, and the elements that affect selecting reliable suppliers. It is an excellent tool for understanding the nuances of supplier selection in a robust supply chain. The research paper uses a variety of methodologies, including fuzzy DEMATEL for analyzing the relationships and impact of criteria, fuzzy Delphi for identifying critical criteria, and fuzzy DEMATEL based on network analysis (FDANP) for determining the weight or degree of importance of the criteria. The research procedure also makes use of fuzzy DEMATEL stages and the Delphi approach. It is important to note that the research is based on a case study conducted in the SAPCO supply chain, which may limit the applicability of the findings to other industries or situations. Moreover, the application of certain techniques and strategies, like fuzzy DEMATEL and fuzzy

Delphi, may have inherent limitations related to subjectivity and the interpretation of imprecise data.

It has been proposed by (Jindal et al., 2021) to emphasize the significance of analytical capability and operational flexibility in determining a company's supply chain agility (SCA) in order to understand the indirect effects of IT infrastructure and the sharing of supply chain information on a company's SCA. The study highlights the crucial role that operational flexibility and analytical proficiency play in enhancing a company's agility and provides insightful information about the causes and effects of implementing Supply Chain Agility, or SCA. Understanding the causal relationships between the attributes that impact SCA is improved by applying the Fuzzy DEMATEL technique to evaluate the attributes that influence SCA's operational flexibility and analytical capability. The study makes use of the Fuzzy DEMATEL technique to evaluate the relationships between the variables that affect supply chain agility (SCA). This tactic has been extended to improve judgment in a variety of circumstances, including vague and imprecise data. In order to support the research, the study additionally looks at 346 papers that were printed in international journals between 2006 and 2016. This provides a comprehensive literature analysis. Moreover, the study draws upon other studies that have utilized the Fuzzy DEMATEL approach for various purposes, demonstrating the relevance and effectiveness of the technique in decision-making processes. The specific dimensions and criteria outlined in the research may limit the findings' applicability. Furthermore, the paper does not address any potential drawbacks or impediments related to the application of the Fuzzy DEMATEL approach. One could argue that this omission limits the ability to provide a complete understanding of the study strategy.

A fuzzy logic technique has been proposed to assess the recyclability of materials, taking into account factors like economics, technology, quality of recycled materials, legislative backing, and environmental impact. This method presents a fresh perspective on waste management and can be used as a useful tool for national policy-making and environmental decision-making. The authors also conducted a sensitivity analysis in order to identify the critical factors influencing material recycling. Resource economists can use this technique to help prioritize important factors that improve recyclability. The research uses a methodology that uses fuzzy logic and "if-then" rules to define recyclability from a global perspective and analyze the main important factors. Six popular materials were used in the calculation of the recyclability index by the authors: aluminum, copper, nickel, paper, plastic, and glass. This was accomplished using a quantitative scale with a range of 0 to 1 and a qualitative evaluation that made use of linguistic criteria. Furthermore, the article provides a thorough strategy for creating a definition of recyclability that is relevant to all situations. It also looks into how materials deteriorate during recycling, such as how paper's mechanical properties change and whether or not metals and glass can be recycled again with little loss of quality. However, the work is limited because it does not include the indicator TAX in the analysis, which could be important for assessing recyclability at the national level. Furthermore, bias may be introduced into the assessment due to the subjective appraisal of some metrics, such as the degree of public recycling engagement and the efficiency of collection and transportation networks.

The benefits of these strategies for lowering supply risk and advancing environmental sustainability have been highlighted by a study (Fernández-Miguel et al., 2022) that looked at the complexity of supply chains during disruptions and reshoring and nearshoring techniques as viable solutions for unplanned supply termination. The dearth of information regarding the application of nearshoring and reshoring tactics in input-sourcing processes in the literature is the subject of this study. This research improves understanding of the complexity of the systems in the supply chain of the ceramics sector and provides specific examples of the transdisciplinary approach to addressing production process complexity. Several technical and management analytical techniques, including sectoral scenario analysis, strategic design of alternative scenarios, technology performance analysis, and environmental effect evaluation, are combined in the article's transdisciplinary methodology. The research has limitations even if it does not state clearly what restrictions apply. Specifically, it does not point out any clear drawbacks associated with using the strategies. Moreover, because this study is scenario-based, its conclusions are arbitrary and vulnerable to revision.

This study presents a Circular Business Model (CBM) to explore the transition from a linear to a circular economy and offer a way to integrate sustainability principles in a manufacturing context (Garcia-Muiña et al., 2018). Through changes to the business model and the use of data from impact assessment techniques like Life Cycle Assessment (LCA), Life Cycle Costing (LCC), and Social Life Cycle Assessment (S-LCA), the CBM incorporates sustainability ideas into the company's strategy. The study emphasizes how important technology is to improving business processes and ensuring their sustainability over the long run. It also stresses that technology should aim to achieve both process improvement and sustainability. The study uses quantitative approaches in conjunction with a case study to verify the system and a qualitative approach to build theoretical concepts. In order to examine and quantify the effects on the environment, economy, and society, the study makes use of impact assessment approaches, such as Life Cycle Assessment (LCA), Life Cycle Costing (LCC), and Social Life Cycle Assessment (S-LCA), as defined by ISO standards. Although no specific boundaries are mentioned, this method's qualitative character raises questions regarding its applicability in everyday circumstances. Moreover, there is still uncertainty on the best way to implement in a changing society.

Contini et al. (2023) have addressed the lack of appropriate indicators for the ceramic industry by proposing a set of key performance indicators (KPIs) to monitor sustainability. This fills a gap in the literature and emphasizes the significance of investing in Industry 4.0 technologies and process digitization to obtain up-to-date and real-time data for sustainability monitoring. The study offers a technique for self-monitoring sustainability and highlights how the suggested KPIs and process digitization can be applied to different manufacturing firms. It recommends creating a "Sustainability Digital Twin" as a tool to assist business managers in making defensible choices and creating products that consider every facet of sustainability. In order to provide readers with a thorough understanding of how ceramic enterprises assess their own sustainability, the article uses a particular ceramic company as a point of reference and gathers information from the company, its suppliers, and its clients. Through a case study of a ceramic company, it presents a set of sustainability performance indicators for ceramic companies and illustrates the application of this methodology. According to the report, most ceramic businesses do not currently have a formal sustainability plan in place, and data and information are frequently ambiguous or useless. The records frequently make no mention of the existence of a firm data monitoring system.

Real-world case studies have been conducted to evaluate the feasibility of applying circular economy solutions in the ceramic industry. These studies (Almeida et al., 2016) provide promising results regarding the eco-innovation potential of the industry. This study centers on the main benefits and obstacles related to the implementation of circular economy strategies in the ceramic industry. The article examines how circular economy concepts might be applied to the ceramics industry and offers specific examples of studies that have been done in this area. The paper identifies a number of areas that should be improved upon to help the ceramics industry maximize the circular economy process. These include minimizing the high costs associated with the process, addressing the uncertainty surrounding the quality of secondary raw materials, and resolving legal and administrative issues pertaining to waste management.

Life Cycle Analysis (LCA) is used in the publication "Ceramic Cup vs. Paper Cup" (Martin et al., 2018) to assess the environmental effects of reusable ceramic mugs with disposable paper cups. The manufacture, transportation, use, and disposal phases of each product's life cycle are taken into account by the LCA approach employed in the study. The analysis provides a thorough evaluation of the environmental performance of each type of cup by assessing multiple environmental effect categories, including resource use, freshwater eutrophication, and the potential for climate change.

2.1 Objectives

Our thesis' main goal is to conduct a comprehensive analysis of Bangladesh's ceramic industry, with a focus on supply chain sustainability management. Our primary goal is to offer practical advice and ideas for improving sustainability in this specific industry. We will apply a sophisticated method known as the Fuzzy Decision-Making Trial and Evaluation Laboratory (Fuzzy DEMATEL) method to do this. Fuzzy logic and DEMATEL technology are used in this method to examine the complex web of relationships between many components that affect the supply chain's sustainability. The aims we aim to achieve are as follows:

1. To conduct a complete analysis of the current state of the ceramic industry in Bangladesh, taking into account its manufacturing processes, resource usage, and environmental effects (Azim et al., 2015).
2. To determine the main elements that support and hinder the implementation of sustainable supply chain management in the ceramic industry (Zubayer et al., 2019).
3. to model and analyze the intricate interactions between the several elements that both promote and impede advancement using the Fuzzy DEMATEL technique (Khan et al., 2022).
4. The aim of this project is to demonstrate the usefulness and effectiveness of the Fuzzy DEMATEL method in order to advance the state of knowledge on sustainable supply chain management

2.2 Targeted Industries

Our main area of interest is Bangladesh's ceramic industry, which comprises both its domestic and export-oriented industries. Our investigation will include a wide range of topics, including distribution networks, logistical operations, and manufacturing processes (Azim et al., 2015).

2.3 Geographical Scope

Our research is exclusively focused on Bangladesh, considering the distinct difficulties and opportunities faced by the Ceramic Industry in the country.

2.4 Methodological Approach

Our primary tool for analyzing and simulating the intricate relationships between numerous factors that affect supply chain sustainability will be the fuzzy DEMATEL approach. Çelik and Arslankaya (2023) state that we may effectively handle imprecise and uncertain data by including fuzzy logic into the DEMATEL framework. This allows us to correctly portray real-world scenarios.

2.5 Data Gathering

Both primary and secondary sources will be used in the data collection process. This will entail looking at company reports, conducting interviews, doing surveys, and analyzing trade periodicals. Our qualitative and quantitative analyses will be built upon the data that has been gathered (Islam et al., 2019).

2.6 Anticipated Outcomes

The objective of our thesis is to perform a comprehensive analysis of Bangladesh's ceramic industry, with a specific emphasis on the key factors influencing the supply chain's sustainability. The study will offer insightful details about the industry's benefits, drawbacks, prospective growth areas, and hazards in addition to useful recommendations for enhancing sustainability all the way up the supply chain (Çelik & Arslankaya, 2023).

2.7 Significance

Our investigation will yield valuable insights and recommendations for policymakers, industry professionals, and fellow researchers who seek to advance sustainability in the Ceramic Industry. Additionally, our findings will contribute significantly to the broader field of sustainable supply chain management. According to M. I. Hossain et al. (2023), our thesis will demonstrate the effectiveness of the Fuzzy DEMATEL technique in addressing complex real-world problems, which will have practical implications beyond the particular industry environment

CHAPTER 03: METHODOLOGY

In order to investigate and understand the complexities of sustainable supply chain management in Bangladesh's ceramic industry, we utilized the Fuzzy Decision Making Trial and Evaluation Laboratory (DEMATEL) approach in this study. We were able to carefully identify and assess the relationships between various supply chain components by using this scientific methodology. The process began with the collection of expert opinions. A professional in the field provided qualitative assessments of the relationships between various factors that impact sustainability. After that, the information was converted into a fuzzy matrix using fuzzy logic principles to handle ambiguity and subjective evaluations. We distinguished between causes—factors that may be actively changed to bring about changes—and effects—results that are impacted by these changes—by applying the DEMATEL approach to transform the unclear matrix into a clear cause-and-effect diagram. This methodology enabled a comprehensive and in-depth analysis of the supply chain, highlighting critical domains for improvement and intervention in the pursuit of sustainability.

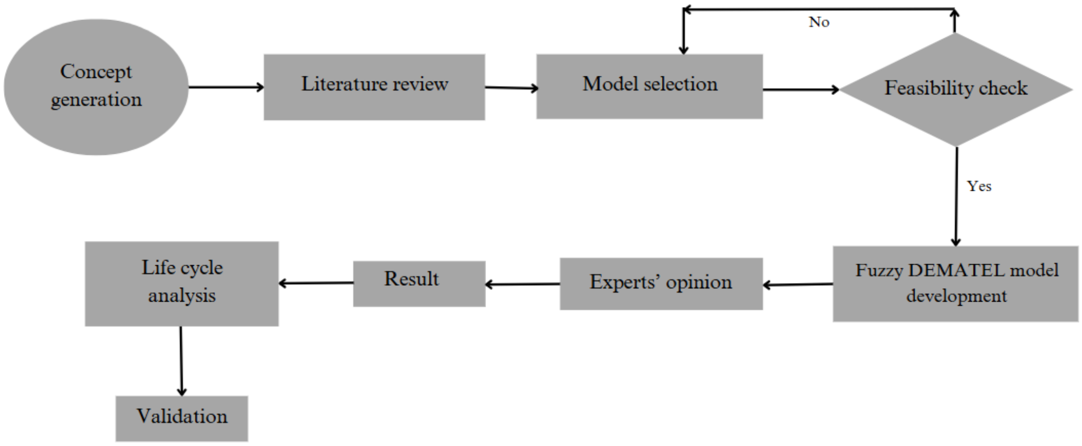


Figure 1.1: Implications of Fuzzy DEMATEL

3.1 Aspects Selection

Our study is based on a thorough questionnaire that was created to collect professional comments on a range of topics related to the supply chain of the ceramic sector. The 17 characteristics that were previously discovered are covered by this questionnaire and are divided into three categories: social, environmental, and economic. To make sure that every question on the questionnaire appropriately captures the crucial elements impacting sustainability in the ceramics sector, a comprehensive literature assessment was conducted throughout the questionnaire's preparation. The questionnaire allows specialists to indicate the strength of links between various elements using a Likert scale, which ranges from 1 (least effect or significance) to 5 (most impact or importance).

Table 1.1*:* List of Aspects Categorized in 4 Perspectives and their Effects

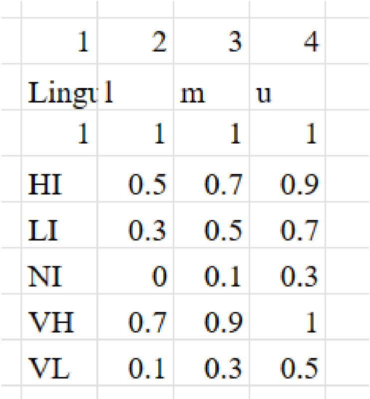
Perspective	Aspect	Effect	Source
Economic	(A1) Cost Optimization	maximizing cost-effectiveness by using sustainable approaches to cut production and operating costs	(Ketokivi & Mahoney, 2020)
	(A2) Sustainable Investment Returns	Calculating the financial return on investments made in environmentally friendly supply chain techniques	(Mefford, 2011)
	(A3) Competitive Edge in Market	Evaluating how eco-friendly approaches boost market position and consumer preference	(Hong et al., 2018)
	(A4) Resource Efficiency in Operations	Maximizing resource efficiency to curtail waste and enhance production efficacy. Environmental Category	(Kumar et al., 2021)
Environment	(A5) Energy Management	Strategies for lowering energy use in manufacturing	(Ivanov, 2018)

		processes	
	(A6) Greenhouse Gas Emissions Assessment	Evaluating and curtailing carbon emissions in the ceramic supply chain	(Cuviella-Suárez et al., 2018)
	(A7) Water Resource Management	Techniques for effective water preservation in industrial processes	(Ibn-Mohammed et al., 2019)
	(A8) Minimizing Industrial Waste	Approaches to reduce waste production and promote recycling	(Dondi et al., 2021)
	(A9) Sustainable Raw Material Acquisition	Ensuring the procurement of raw materials is sustainable and ethical	(S. S. Hossain & Roy, 2020)
Social	(A10) Workforce Welfare and Safety	Guaranteeing workers' rights, safety, and overall well-being	(Hemphill & White Iii, 2018)
	(A11) Responsible Sourcing Practices	Ensuring ethically and responsibly sourced materials	(Oka et al., 2020)
	(A12) Enhancing Health and Safety Protocols	Strengthening health and safety measures for industrial employees	(Bessa et al., 2020)
	(A13) Supplier Partnership Development	Fostering positive and ethical relationships with suppliers	(Huq & Stevenson, 2020)
Common	(A14) Sustainability-Oriented Regulatory Adherence	Complying with and shaping policies related to eco-friendly practices	(Vieira de Souza et al., 2018)
	(A15) Collaborative Sustainable Initiatives	Engaging diverse stakeholders in sustainable efforts within the supply chain	(Appolloni et al., 2022)
	(A16) Sustainable Industry	Evaluating the long-term	(Ferrari et al., 2019)

	Resilience	sustainability and robustness of the ceramic sector	
	(A17) Integrative Corporate Responsibility	Implementing and evaluating the impact of CSR actions on environmental and social sustainability	(Omar et al., 2019)

3.2 Data Collection from Experts

It is customary to consult with at least 15–20 industry experts before applying the Fuzzy DEMATEL approach. We were only able to visit one industry thus far. We visited Shinepukur Ceramics Ltd., one of the well-known ceramic production firms in Bangladesh. He was provided the following table, from which the values were extracted.



1	2	3	4
Lingu	l	m	u
1	1	1	1
HI	0.5	0.7	0.9
LI	0.3	0.5	0.7
NI	0	0.1	0.3
VH	0.7	0.9	1
VL	0.1	0.3	0.5

Figure 1.2*:* Linguistic variables into corresponding TFN table

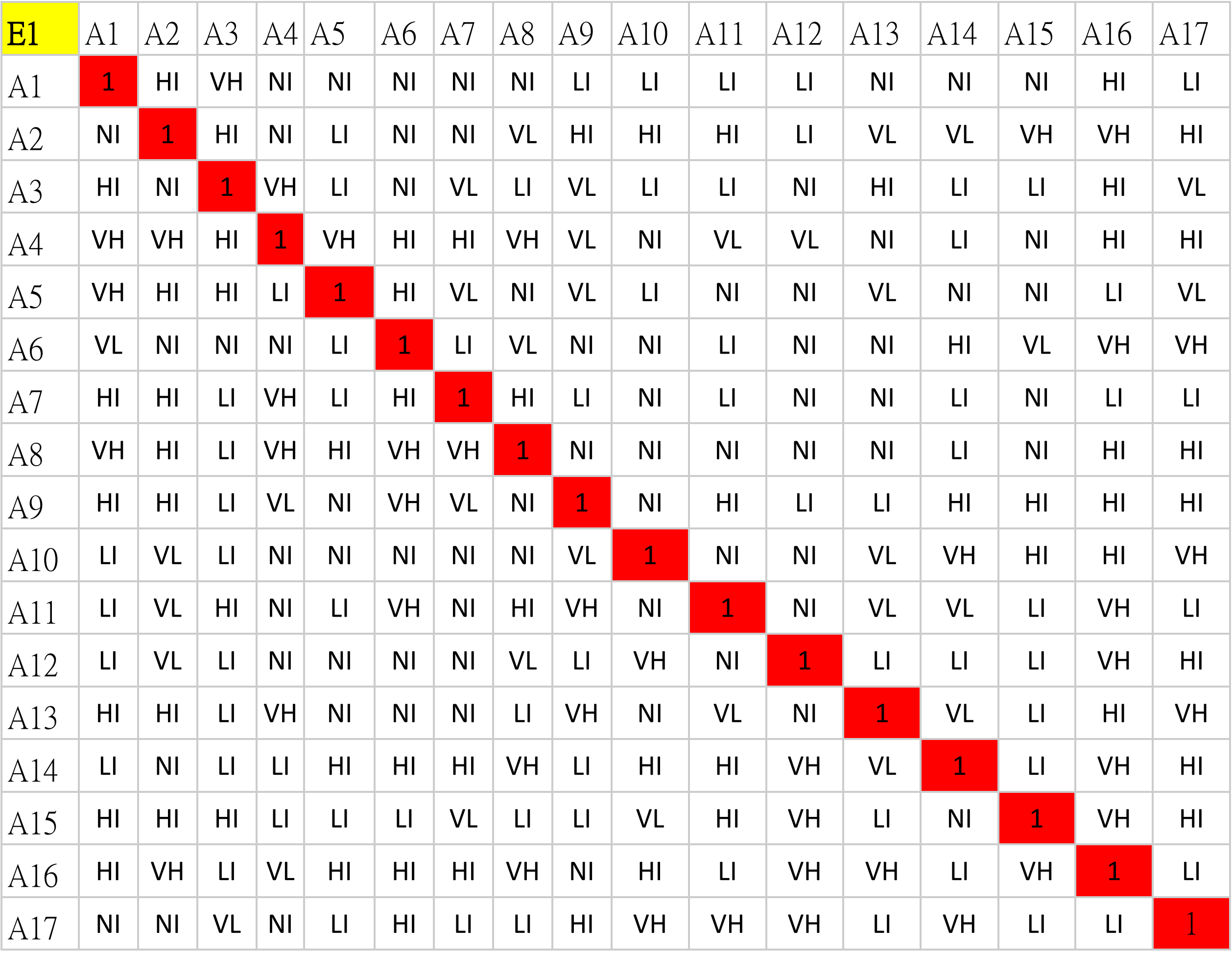
The expert must assess how one factor (the row aspect) influences another (the column aspect). Aspects are classified as having High Influence (HI) or No Influence (NI), depending on how much of an influence they have on the other aspect. The opinions of specialists from a few well-known ceramic manufacturing enterprises in Bangladesh are included below.

Expert 01:

Faridul Islam,

Plant Manager,

Shinepukur Ceramics Ltd.



E1	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	A12	A13	A14	A15	A16	A17
A1	1	HI	VH	NI	NI	NI	NI	NI	LI	LI	LI	LI	NI	NI	NI	HI	LI
A2	NI	1	HI	NI	LI	NI	NI	VL	HI	HI	HI	LI	VL	VL	VH	VH	HI
A3	HI	NI	1	VH	LI	NI	VL	LI	VL	LI	LI	NI	HI	LI	LI	HI	VL
A4	VH	VH	HI	1	VH	HI	HI	VH	VL	NI	VL	VL	NI	LI	NI	HI	HI
A5	VH	HI	HI	LI	1	HI	VL	NI	VL	LI	NI	NI	VL	NI	NI	LI	VL
A6	VL	NI	NI	NI	LI	1	LI	VL	NI	NI	LI	NI	NI	HI	VL	VH	VH
A7	HI	HI	LI	VH	LI	HI	1	HI	LI	NI	LI	NI	NI	LI	NI	LI	LI
A8	VH	HI	LI	VH	HI	VH	VH	1	NI	NI	NI	NI	NI	LI	NI	HI	HI
A9	HI	HI	LI	VL	NI	VH	VL	NI	1	NI	HI	LI	LI	HI	HI	HI	HI
A10	LI	VL	LI	NI	NI	NI	NI	NI	VL	1	NI	NI	VL	VH	HI	HI	VH
A11	LI	VL	HI	NI	LI	VH	NI	HI	VH	NI	1	NI	VL	VL	LI	VH	LI
A12	LI	VL	LI	NI	NI	NI	NI	VL	LI	VH	NI	1	LI	LI	LI	VH	HI
A13	HI	HI	LI	VH	NI	NI	NI	LI	VH	NI	VL	NI	1	VL	LI	HI	VH
A14	LI	NI	LI	LI	HI	HI	HI	VH	LI	HI	HI	VH	VL	1	LI	VH	HI
A15	HI	HI	HI	LI	LI	LI	VL	LI	LI	VL	HI	VH	LI	NI	1	VH	HI
A16	HI	VH	LI	VL	HI	HI	HI	VH	NI	HI	LI	VH	VH	LI	VH	1	LI
A17	NI	NI	VL	NI	LI	HI	LI	LI	HI	VH	VH	VH	LI	VH	LI	LI	1

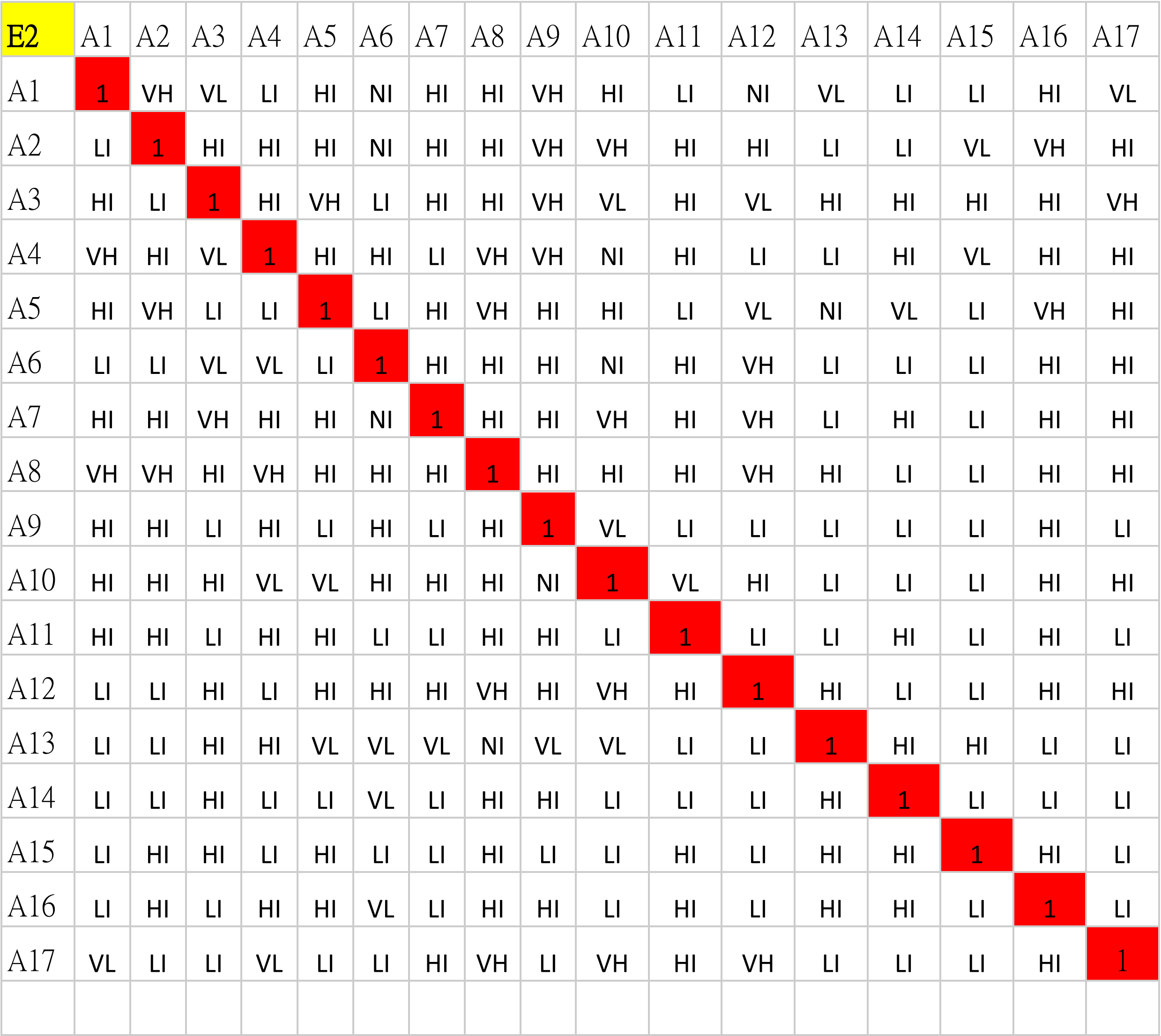
Figure 2.1: Data Collection from Expert 01

Expert 02:

Tariq Ibrahim Ahmad,

AGM, IE & Lean,

Paragon Ceramics Industries Ltd.



E2	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	A12	A13	A14	A15	A16	A17
A1	1	VH	VL	LI	HI	NI	HI	HI	VH	HI	LI	NI	VL	LI	LI	HI	VL
A2	LI	1	HI	HI	HI	NI	HI	HI	VH	VH	HI	HI	LI	LI	VL	VH	HI
A3	HI	LI	1	HI	VH	LI	HI	HI	VH	VL	HI	VL	HI	HI	HI	HI	VH
A4	VH	HI	VL	1	HI	HI	LI	VH	VH	NI	HI	LI	LI	HI	VL	HI	HI
A5	HI	VH	LI	LI	1	LI	HI	VH	HI	HI	LI	VL	NI	VL	LI	VH	HI
A6	LI	LI	VL	VL	LI	1	HI	HI	HI	NI	HI	VH	LI	LI	LI	HI	HI
A7	HI	HI	VH	HI	HI	NI	1	HI	HI	VH	HI	VH	LI	HI	LI	HI	HI
A8	VH	VH	HI	VH	HI	HI	HI	1	HI	HI	HI	VH	HI	LI	LI	HI	HI
A9	HI	HI	LI	HI	LI	HI	LI	HI	1	VL	LI	LI	LI	LI	LI	HI	LI
A10	HI	HI	HI	VL	VL	HI	HI	HI	NI	1	VL	HI	LI	LI	LI	HI	HI
A11	HI	HI	LI	HI	HI	LI	LI	HI	HI	LI	1	LI	LI	HI	LI	HI	LI
A12	LI	LI	HI	LI	HI	HI	HI	VH	HI	VH	HI	1	HI	LI	LI	HI	HI
A13	LI	LI	HI	HI	VL	VL	VL	NI	VL	VL	LI	LI	1	HI	HI	LI	LI
A14	LI	LI	HI	LI	LI	VL	LI	HI	HI	LI	LI	LI	HI	1	LI	LI	LI
A15	LI	HI	HI	LI	HI	LI	LI	HI	LI	LI	HI	LI	HI	HI	1	HI	LI
A16	LI	HI	LI	HI	HI	VL	LI	HI	HI	LI	HI	LI	HI	HI	LI	1	LI
A17	VL	LI	LI	VL	LI	LI	HI	VH	LI	VH	HI	VH	LI	LI	LI	HI	1

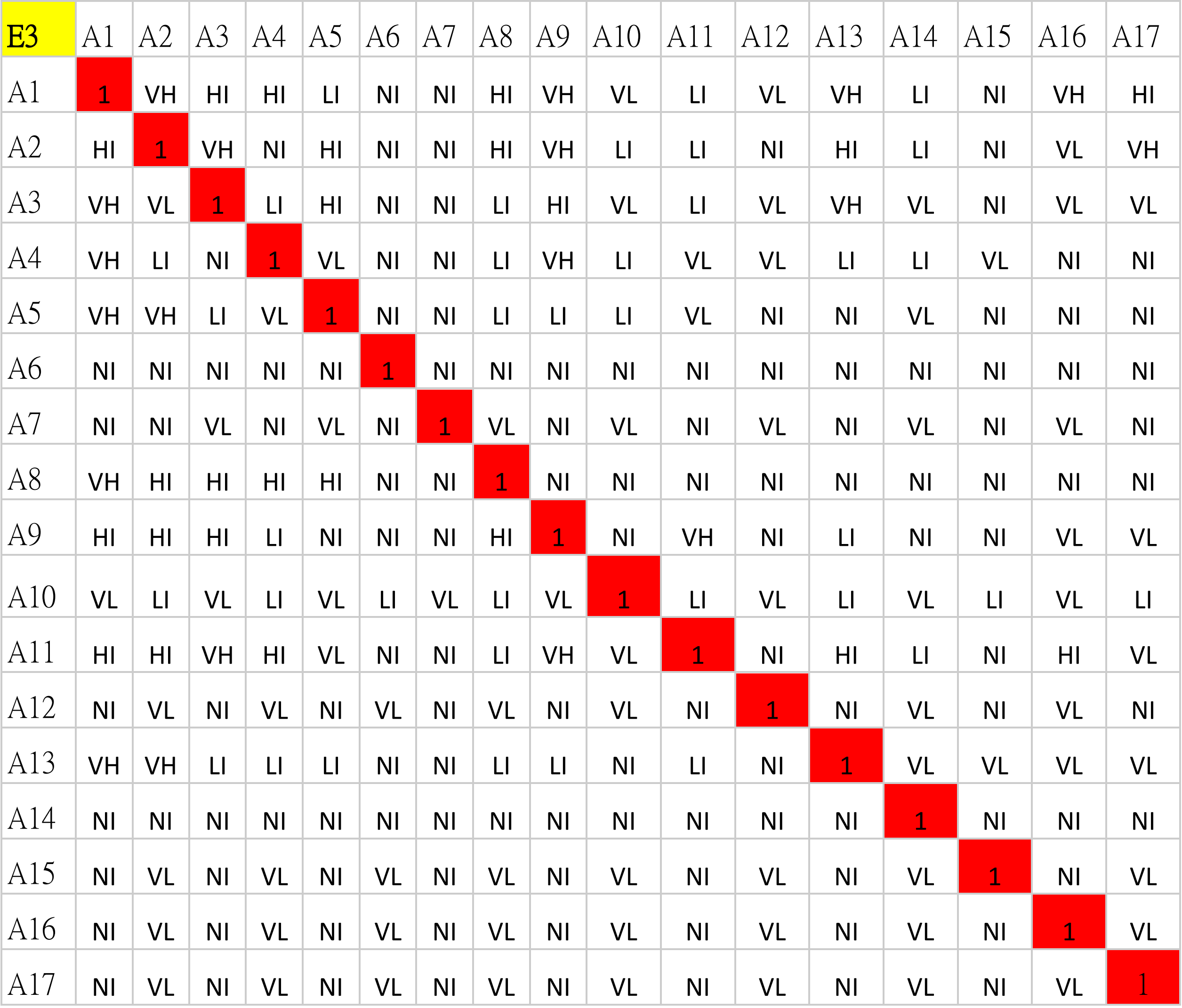
Figure 2.2: Data Collection from Expert 02

Expert 03:

Suhan Ahmed,

AGM - Production,

Paragon Ceramics Industries Ltd.



E3	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	A12	A13	A14	A15	A16	A17
A1	1	VH	HI	HI	LI	NI	NI	HI	VH	VL	LI	VL	VH	LI	NI	VH	HI
A2	HI	1	VH	NI	HI	NI	NI	HI	VH	LI	LI	NI	HI	LI	NI	VL	VH
A3	VH	VL	1	LI	HI	NI	NI	LI	HI	VL	LI	VL	VH	VL	NI	VL	VL
A4	VH	LI	NI	1	VL	NI	NI	LI	VH	LI	VL	VL	LI	LI	VL	NI	NI
A5	VH	VH	LI	VL	1	NI	NI	LI	LI	LI	VL	NI	NI	VL	NI	NI	NI
A6	NI	NI	NI	NI	NI	1	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI
A7	NI	NI	VL	NI	VL	NI	1	VL	NI	VL	NI	VL	NI	VL	NI	VL	NI
A8	VH	HI	HI	HI	HI	NI	NI	1	NI	NI	NI	NI	NI	NI	NI	NI	NI
A9	HI	HI	HI	LI	NI	NI	NI	HI	1	NI	VH	NI	LI	NI	NI	VL	VL
A10	VL	LI	VL	LI	VL	LI	VL	LI	VL	1	LI	VL	LI	VL	LI	VL	LI
A11	HI	HI	VH	HI	VL	NI	NI	LI	VH	VL	1	NI	HI	LI	NI	HI	VL
A12	NI	VL	NI	VL	NI	VL	NI	VL	NI	VL	NI	1	NI	VL	NI	VL	NI
A13	VH	VH	LI	LI	LI	NI	NI	LI	LI	NI	LI	NI	1	VL	VL	VL	VL
A14	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	1	NI	NI	NI
A15	NI	VL	NI	VL	NI	VL	NI	VL	NI	VL	NI	VL	NI	VL	1	NI	VL
A16	NI	VL	NI	VL	NI	VL	NI	VL	NI	VL	NI	VL	NI	VL	NI	1	VL
A17	NI	VL	NI	VL	NI	VL	NI	VL	NI	VL	NI	VL	NI	VL	NI	VL	1

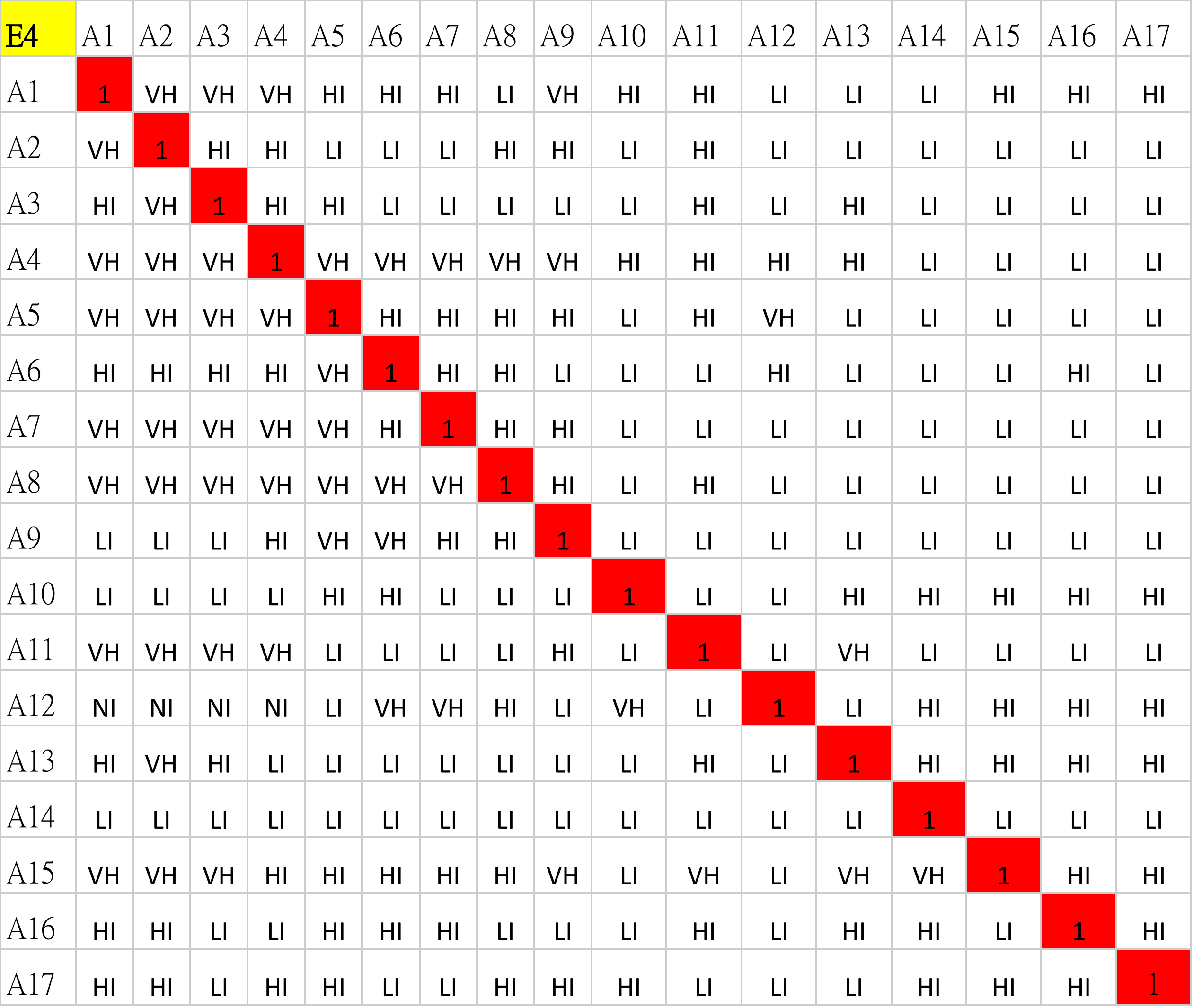
Figure 2.3: Data Collection from Expert -03

Expert 04:

Nayem Shahariar,

Assistant Manager - Planning,

DBL Ceramics Ltd.



E4	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	A12	A13	A14	A15	A16	A17
A1	1	VH	VH	VH	HI	HI	HI	LI	VH	HI	HI	LI	LI	LI	HI	HI	HI
A2	VH	1	HI	HI	LI	LI	LI	HI	HI	LI	HI	LI	LI	LI	LI	LI	LI
A3	HI	VH	1	HI	HI	LI	LI	LI	LI	LI	HI	LI	HI	LI	LI	LI	LI
A4	VH	VH	VH	1	VH	VH	VH	VH	VH	HI	HI	HI	HI	LI	LI	LI	LI
A5	VH	VH	VH	VH	1	HI	HI	HI	HI	LI	HI	VH	LI	LI	LI	LI	LI
A6	HI	HI	HI	HI	VH	1	HI	HI	LI	LI	LI	HI	LI	LI	LI	HI	LI
A7	VH	VH	VH	VH	VH	HI	1	HI	HI	LI	LI	LI	LI	LI	LI	LI	LI
A8	VH	VH	VH	VH	VH	VH	VH	1	HI	LI	HI	LI	LI	LI	LI	LI	LI
A9	LI	LI	LI	HI	VH	VH	HI	HI	1	LI	LI	LI	LI	LI	LI	LI	LI
A10	LI	LI	LI	LI	HI	HI	LI	LI	LI	1	LI	LI	HI	HI	HI	HI	HI
A11	VH	VH	VH	VH	LI	LI	LI	LI	HI	LI	1	LI	VH	LI	LI	LI	LI
A12	NI	NI	NI	NI	LI	VH	VH	HI	LI	VH	LI	1	LI	HI	HI	HI	HI
A13	HI	VH	HI	LI	LI	LI	LI	LI	LI	LI	HI	LI	1	HI	HI	HI	HI
A14	LI	LI	LI	LI	LI	LI	LI	LI	LI	LI	LI	LI	LI	1	LI	LI	LI
A15	VH	VH	VH	HI	HI	HI	HI	HI	VH	LI	VH	LI	VH	VH	1	HI	HI
A16	HI	HI	LI	LI	HI	HI	HI	LI	LI	LI	HI	LI	HI	HI	LI	1	HI
A17	HI	HI	LI	HI	HI	LI	LI	HI	HI	HI	LI	LI	LI	HI	HI	HI	1

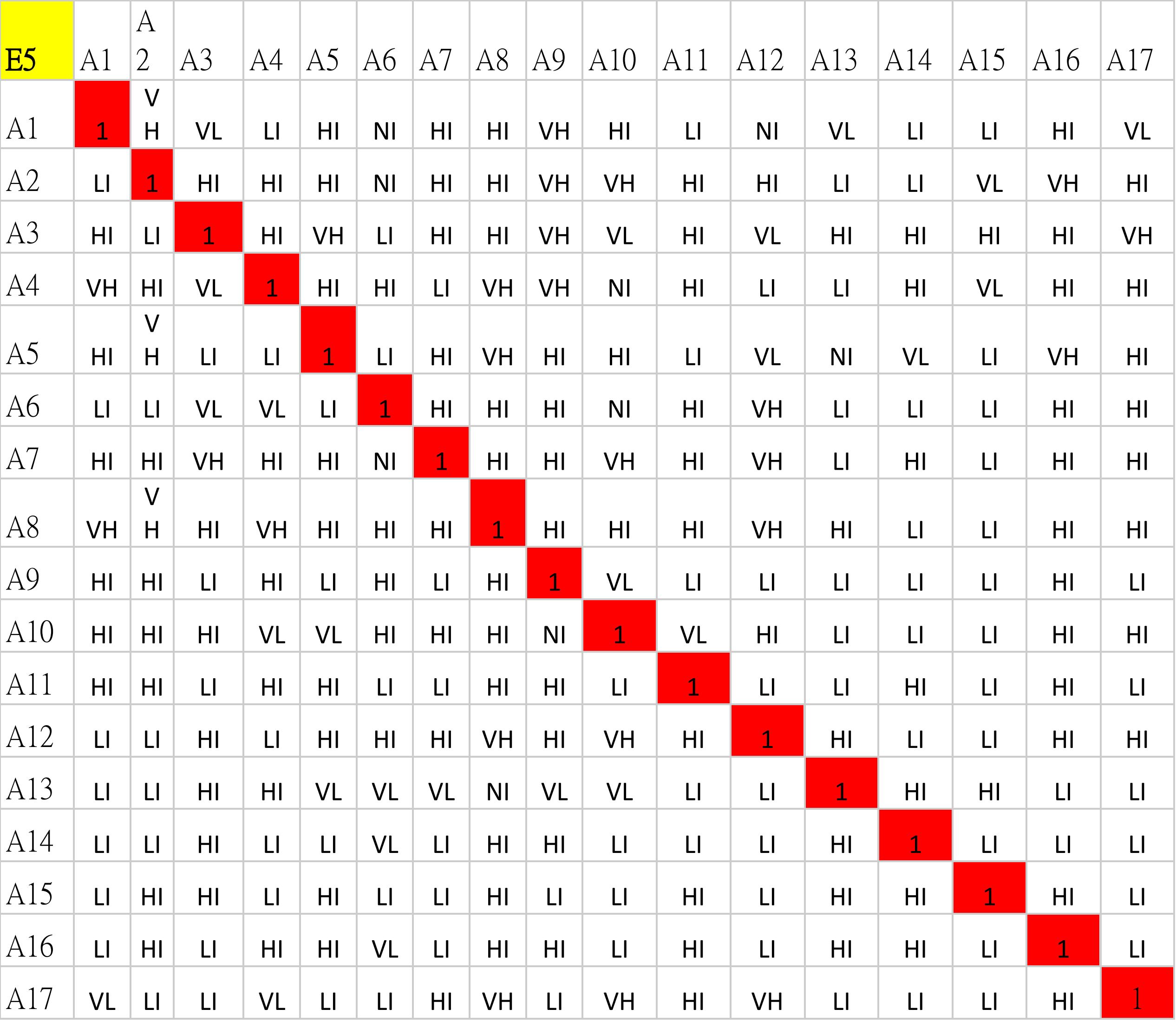
Figure 2.4: Data Collection from Expert -04

Expert 05:

Shajidul Islam,

Senior Engineer - Quality Control,

Great Wall Ceramic Ltd.



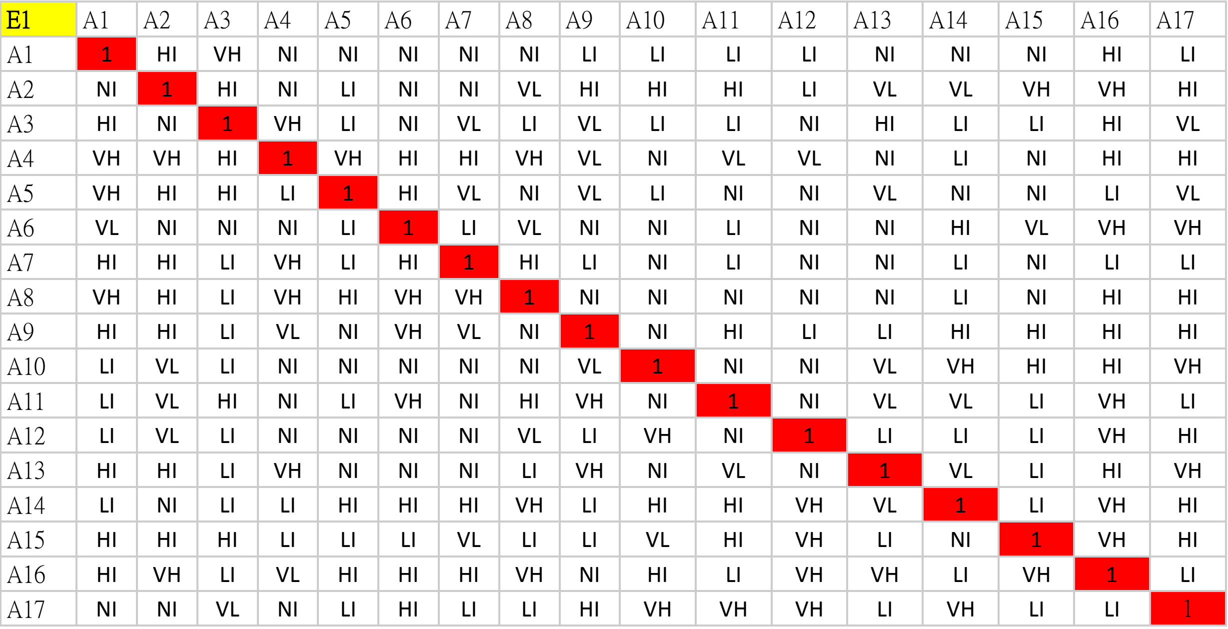
E5	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	A12	A13	A14	A15	A16	A17
A1	1	VH	VL	LI	HI	NI	HI	HI	VH	HI	LI	NI	VL	LI	LI	HI	VL
A2	LI	1	HI	HI	HI	NI	HI	HI	VH	VH	HI	HI	LI	LI	VL	VH	HI
A3	HI	LI	1	HI	VH	LI	HI	HI	VH	VL	HI	VL	HI	HI	HI	HI	VH
A4	VH	HI	VL	1	HI	HI	LI	VH	VH	NI	HI	LI	LI	HI	VL	HI	HI
A5	HI	VH	LI	LI	1	LI	HI	VH	HI	HI	LI	VL	NI	VL	LI	VH	HI
A6	LI	LI	VL	VL	LI	1	HI	HI	HI	NI	HI	VH	LI	LI	LI	HI	HI
A7	HI	HI	VH	HI	HI	NI	1	HI	HI	VH	HI	VH	LI	HI	LI	HI	HI
A8	VH	VH	HI	VH	HI	HI	HI	1	HI	HI	HI	VH	HI	LI	LI	HI	HI
A9	HI	HI	LI	HI	LI	HI	LI	HI	1	VL	LI	LI	LI	LI	LI	HI	LI
A10	HI	HI	HI	VL	VL	HI	HI	HI	NI	1	VL	HI	LI	LI	LI	HI	HI
A11	HI	HI	LI	HI	HI	LI	LI	HI	HI	LI	1	LI	LI	HI	LI	HI	LI
A12	LI	LI	HI	LI	HI	HI	HI	VH	HI	VH	HI	1	HI	LI	LI	HI	HI
A13	LI	LI	HI	HI	VL	VL	VL	NI	VL	VL	LI	LI	1	HI	HI	LI	LI
A14	LI	LI	HI	LI	LI	VL	LI	HI	HI	LI	LI	LI	HI	1	LI	LI	LI
A15	LI	HI	HI	LI	HI	LI	LI	HI	LI	LI	HI	LI	HI	HI	1	HI	LI
A16	LI	HI	LI	HI	HI	VL	LI	HI	HI	LI	HI	LI	HI	HI	LI	1	LI
A17	VL	LI	LI	VL	LI	LI	HI	VH	LI	VH	HI	VH	LI	LI	LI	HI	1

Figure 2.5: Data Collection from Expert-05

3.3 Detailed Method of Fuzzy DEMATEL Method

A systematic process called the Fuzzy Decision Trial and Evaluation Laboratory (DEMATEL) method converts experts' fuzzy views into a distinct cause-and-effect link between different parameters. According to Chang et al. (2017), this approach excels at handling the innate uncertainties and arbitrary assessments that come with complex systems like supply chain management.

Step 01: Converting the linguistic variables into corresponding Triangular Fuzzy Numbers.



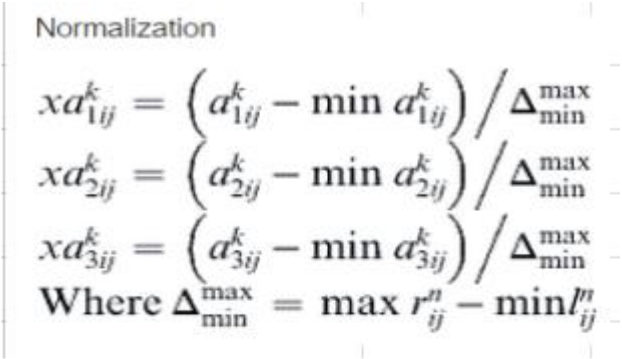
E1	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	A12	A13	A14	A15	A16	A17
A1	1	HI	VH	NI	NI	NI	NI	NI	LI	LI	LI	LI	NI	NI	NI	HI	LI
A2	NI	1	HI	NI	LI	NI	NI	VL	HI	HI	HI	LI	VL	VL	VH	VH	HI
A3	HI	NI	1	VH	LI	NI	VL	LI	VL	LI	LI	NI	HI	LI	LI	HI	VL
A4	VH	VH	HI	1	VH	HI	HI	VH	VL	NI	VL	VL	NI	LI	NI	HI	HI
A5	VH	HI	HI	LI	1	HI	VL	NI	VL	LI	NI	NI	VL	NI	NI	LI	VL
A6	VL	NI	NI	NI	LI	1	LI	VL	NI	NI	LI	NI	NI	HI	VL	VH	VH
A7	HI	HI	LI	VH	LI	HI	1	HI	LI	NI	LI	NI	NI	LI	NI	LI	LI
A8	VH	HI	LI	VH	HI	VH	VH	1	NI	NI	NI	NI	NI	LI	NI	HI	HI
A9	HI	HI	LI	VL	NI	VH	VL	NI	1	NI	HI	LI	LI	HI	HI	HI	HI
A10	LI	VL	LI	NI	NI	NI	NI	NI	VL	1	NI	NI	VL	VH	HI	HI	VH
A11	LI	VL	HI	NI	LI	VH	NI	HI	VH	NI	1	NI	VL	VL	LI	VH	LI
A12	LI	VL	LI	NI	NI	NI	NI	VL	LI	VH	NI	1	LI	LI	LI	VH	HI
A13	HI	HI	LI	VH	NI	NI	NI	LI	VH	NI	VL	NI	1	VL	LI	HI	VH
A14	LI	NI	LI	LI	HI	HI	HI	VH	LI	HI	HI	VH	VL	1	LI	VH	HI
A15	HI	HI	HI	LI	LI	LI	VL	LI	LI	VL	HI	VH	LI	NI	1	VH	HI
A16	HI	VH	LI	VL	HI	HI	HI	VH	NI	HI	LI	VH	VH	LI	VH	1	LI
A17	NI	NI	VL	NI	LI	HI	LI	LI	HI	VH	VH	VH	LI	VH	LI	LI	1

Figure 2.6: Excel Sheet Preview of Expert -01

E1				A1						A2						A3		
	A1	[	1.00	1.00	1.00	]		[	0.500	0.700	0.900	]		[	0.700	0.900	1.000	]
	A2	[	0.00	0.10	0.30	]		[	1.000	1.000	1.000	]		[	0.500	0.700	0.900	]
	A3	[	0.50	0.70	0.90	]		[	0.000	0.100	0.300	]		[	1.000	1.000	1.000	]
	A4	[	0.70	0.90	1.00	]		[	0.700	0.900	1.000	]		[	0.500	0.700	0.900	]
	A5	[	0.70	0.90	1.00	]		[	0.500	0.700	0.900	]		[	0.500	0.700	0.900	]
	A6	[	0.10	0.30	0.50	]		[	0.000	0.100	0.300	]		[	0.000	0.100	0.300	]
	A7	[	0.50	0.70	0.90	]		[	0.500	0.700	0.900	]		[	0.300	0.500	0.700	]
	A8	[	0.70	0.90	1.00	]		[	0.500	0.700	0.900	]		[	0.300	0.500	0.700	]
	A9	[	0.50	0.70	0.90	]		[	0.500	0.700	0.900	]		[	0.300	0.500	0.700	]
	A10	[	0.30	0.50	0.70	]		[	0.100	0.300	0.500	]		[	0.300	0.500	0.700	]
	A11	[	0.30	0.50	0.70	]		[	0.100	0.300	0.500	]		[	0.500	0.700	0.900	]
	A12	[	0.30	0.50	0.70	]		[	0.100	0.300	0.500	]		[	0.300	0.500	0.700	]
	A13	[	0.50	0.70	0.90	]		[	0.500	0.700	0.900	]		[	0.300	0.500	0.700	]
	A14	[	0.30	0.50	0.70	]		[	0.000	0.100	0.300	]		[	0.300	0.500	0.700	]
	A15	[	0.50	0.70	0.90	]		[	0.500	0.700	0.900	]		[	0.500	0.700	0.900	]
	A16	[	0.50	0.70	0.90	]		[	0.700	0.900	1.000	]		[	0.300	0.500	0.700	]
	A17	[	0.00	0.10	0.30	]		[	0.000	0.100	0.300	]		[	0.100	0.300	0.500	]

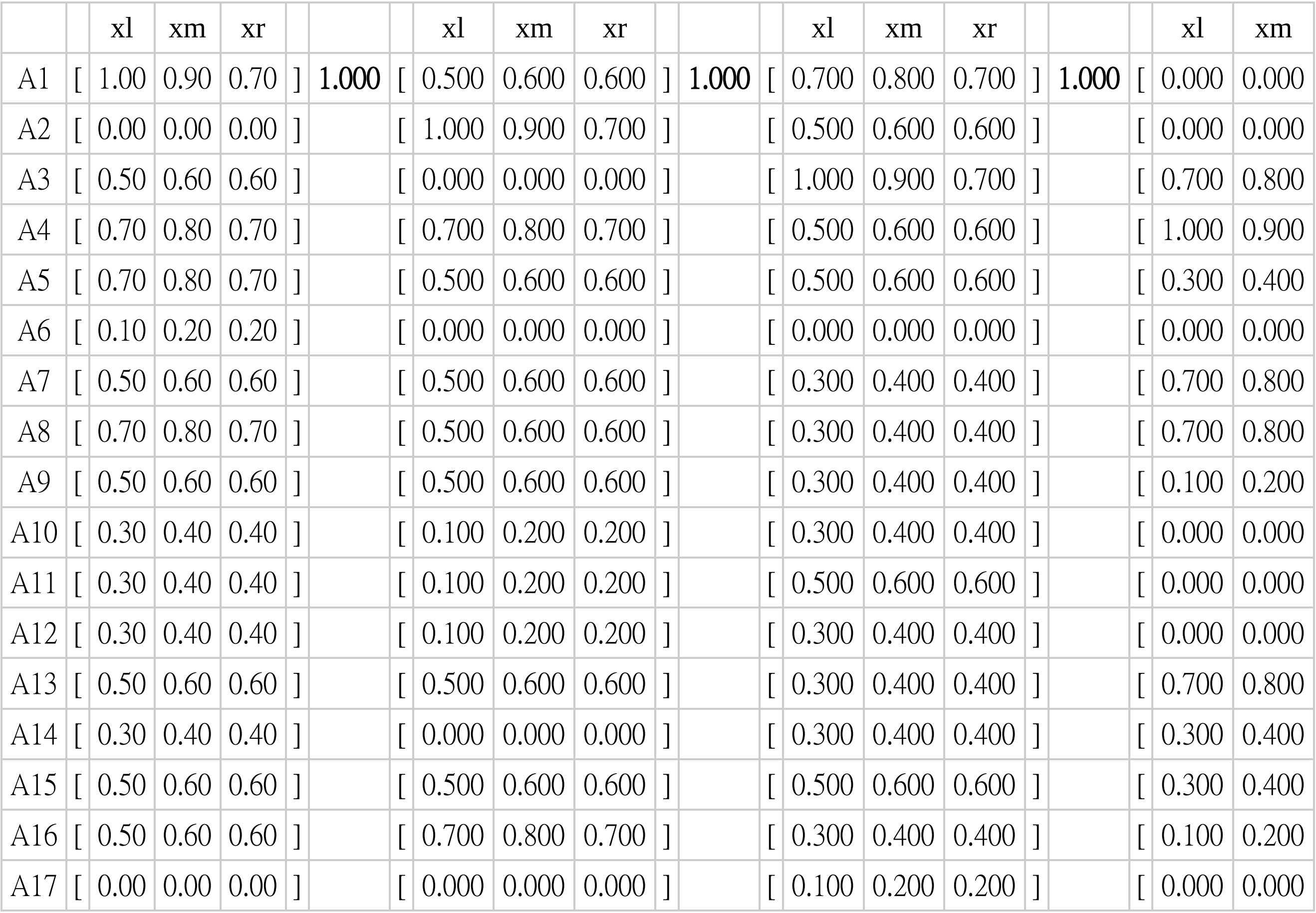
Figure 2.7: Linguistic value to TFN conversion

Step 02: Normalizing the triangular fuzzy numbers which maintains the consistency of the matrix.



Normalization

$$xa_{1ij}^{k} = \left(a_{1ij}^{k} - \min a_{1ij}^{k}\right) / \Delta_{\min}^{\max}$$
$$xa_{2ij}^{k} = \left(a_{2ij}^{k} - \min a_{2ij}^{k}\right) / \Delta_{\min}^{\max}$$
$$xa_{3ij}^{k} = \left(a_{3ij}^{k} - \min a_{3ij}^{k}\right) / \Delta_{\min}^{\max}$$
$$\text{Where } \Delta_{\min}^{\max} = \max r_{ij}^{n} - \min l_{ij}^{n}$$



		xl	xm	xr				xl	xm	xr				xl	xm	xr				xl	xm
A1	[	1.00	0.90	0.70	]	1.000	[	0.500	0.600	0.600	]	1.000	[	0.700	0.800	0.700	]	1.000	[	0.000	0.000
A2	[	0.00	0.00	0.00	]		[	1.000	0.900	0.700	]		[	0.500	0.600	0.600	]		[	0.000	0.000
A3	[	0.50	0.60	0.60	]		[	0.000	0.000	0.000	]		[	1.000	0.900	0.700	]		[	0.700	0.800
A4	[	0.70	0.80	0.70	]		[	0.700	0.800	0.700	]		[	0.500	0.600	0.600	]		[	1.000	0.900
A5	[	0.70	0.80	0.70	]		[	0.500	0.600	0.600	]		[	0.500	0.600	0.600	]		[	0.300	0.400
A6	[	0.10	0.20	0.20	]		[	0.000	0.000	0.000	]		[	0.000	0.000	0.000	]		[	0.000	0.000
A7	[	0.50	0.60	0.60	]		[	0.500	0.600	0.600	]		[	0.300	0.400	0.400	]		[	0.700	0.800
A8	[	0.70	0.80	0.70	]		[	0.500	0.600	0.600	]		[	0.300	0.400	0.400	]		[	0.700	0.800
A9	[	0.50	0.60	0.60	]		[	0.500	0.600	0.600	]		[	0.300	0.400	0.400	]		[	0.100	0.200
A10	[	0.30	0.40	0.40	]		[	0.100	0.200	0.200	]		[	0.300	0.400	0.400	]		[	0.000	0.000
A11	[	0.30	0.40	0.40	]		[	0.100	0.200	0.200	]		[	0.500	0.600	0.600	]		[	0.000	0.000
A12	[	0.30	0.40	0.40	]		[	0.100	0.200	0.200	]		[	0.300	0.400	0.400	]		[	0.000	0.000
A13	[	0.50	0.60	0.60	]		[	0.500	0.600	0.600	]		[	0.300	0.400	0.400	]		[	0.700	0.800
A14	[	0.30	0.40	0.40	]		[	0.000	0.000	0.000	]		[	0.300	0.400	0.400	]		[	0.300	0.400
A15	[	0.50	0.60	0.60	]		[	0.500	0.600	0.600	]		[	0.500	0.600	0.600	]		[	0.300	0.400
A16	[	0.50	0.60	0.60	]		[	0.700	0.800	0.700	]		[	0.300	0.400	0.400	]		[	0.100	0.200
A17	[	0.00	0.00	0.00	]		[	0.000	0.000	0.000	]		[	0.100	0.200	0.200	]		[	0.000	0.000

Figure 2.8: Normalization formula and normalization in Excel

Step 03: Computing the left(xls^{k}_{ij}) and right(xrs^{k}_{ij}) normalized values.

$$xls^{k}_{ij} = xa^{k}_{2ij} \Big/ \left(1 + xa^{k}_{2ij} - xa^{k}_{1ij}\right)$$
$$xrs^{k}_{ij} = xa^{k}_{3ij} \Big/ \left(1 + xa^{n}_{3ij} - xal^{k}_{2ij}\right)$$

	xls	xrs	xls	xrs	xls	xrs	xls	xrs
A1	1.000	0.875	0.545	0.600	0.727	0.778	0.000	0.000
A2	0.000	0.000	1.000	0.875	0.545	0.600	0.000	0.000
A3	0.545	0.600	0.000	0.000	1.000	0.875	0.727	0.778
A4	0.727	0.778	0.727	0.778	0.545	0.600	1.000	0.875
A5	0.727	0.778	0.545	0.600	0.545	0.600	0.364	0.400
A6	0.182	0.200	0.000	0.000	0.000	0.000	0.000	0.000
A7	0.545	0.600	0.545	0.600	0.364	0.400	0.727	0.778
A8	0.727	0.778	0.545	0.600	0.364	0.400	0.727	0.778
A9	0.545	0.600	0.545	0.600	0.364	0.400	0.182	0.200
A10	0.364	0.400	0.182	0.200	0.364	0.400	0.000	0.000
A11	0.364	0.400	0.182	0.200	0.545	0.600	0.000	0.000
A12	0.364	0.400	0.182	0.200	0.364	0.400	0.000	0.000
A13	0.545	0.600	0.545	0.600	0.364	0.400	0.727	0.778
A14	0.364	0.400	0.000	0.000	0.364	0.400	0.364	0.400
A15	0.545	0.600	0.545	0.600	0.545	0.600	0.364	0.400
A16	0.545	0.600	0.727	0.778	0.364	0.400	0.182	0.200
A17	0.000	0.000	0.000	0.000	0.182	0.200	0.000	0.000

Figure 2.9*:* Computing the left and right normalized values

Step 04: Acquiring the crisp values(x^k_{ij}).

$$x_{ij}^{k} = \left\lfloor xls_{ij}^{k}\left(1 - xls_{ij}^{k}\right) + xrs_{ij}^{k} \times xrs_{ij}^{n} \right\rfloor / \left(1 - xls_{ij}^{k} + xrs_{ij}^{k}\right)$$

		xij						xij						xij						xij	
A1		0.875						0.576						0.765						0.000	
A2		0.000						0.875						0.576						0.000	
A3		0.576						0.000						0.875						0.765	
A4		0.765						0.765						0.576						0.875	
A5		0.765						0.576						0.576						0.378	
A6		0.185						0.000						0.000						0.000	
A7		0.576						0.576						0.378						0.765	
A8		0.765						0.576						0.378						0.765	
A9		0.576						0.576						0.378						0.185	
A10		0.378						0.185						0.378						0.000	
A11		0.378						0.185						0.576						0.000	
A12		0.378						0.185						0.378						0.000	
A13		0.576						0.576						0.378						0.765	
A14		0.378						0.000						0.378						0.378	
A15		0.576						0.576						0.576						0.378	
A16		0.576						0.765						0.378						0.185	
A17		0.000						0.000						0.185						0.000	

Figure 2.10*:* Acquiring the crisp values

Step 05: Generating the total normalized crisp values and this is the last step of the Fuzzy method.

$$\tilde{\omega}_{ij}^{k} = \min a_{ij}^{n} + x_{ij}^{n}\Delta_{\min}^{\max}$$

	zij	zij	zij	zij
A1	0.88	0.576	0.765	0.000
A2	0.00	0.875	0.576	0.000
A3	0.58	0.000	0.875	0.765
A4	0.76	0.765	0.576	0.875
A5	0.76	0.576	0.576	0.378
A6	0.19	0.000	0.000	0.000
A7	0.58	0.576	0.378	0.765
A8	0.76	0.576	0.378	0.765
A9	0.58	0.576	0.378	0.185
A10	0.38	0.185	0.378	0.000
A11	0.38	0.185	0.576	0.000
A12	0.38	0.185	0.378	0.000
A13	0.58	0.576	0.378	0.765
A14	0.38	0.000	0.378	0.378
A15	0.58	0.576	0.576	0.378
A16	0.58	0.765	0.378	0.185
A17	0.00	0.000	0.185	0.000

Figure 2.11: Total normalized crisp values generation

Step 06: From this step, the DEMATEL method starts. Obtain the direct relation matrix by aggregating the normalized crisp values from experts.

	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	A12	A13	A14	A15	A16	A17	Row
A1	0.8221	0.6904	0.4612	0.3882	0.3755	0.1571	0.3000	0.4059	0.6689	0.4432	0.3711	0.1726	0.2871	0.2555	0.2200	0.5529	0.3153	6.8872
A2	0.3882	0.8130	0.5835	0.3153	0.4508	0.1350	0.2600	0.4830	0.6741	0.5567	0.4908	0.3661	0.3634	0.2926	0.2529	0.2529	0.5129	7.1915
A3	0.5835	0.3100	0.8221	0.5438	0.5610	0.2861	0.2971	0.4417	0.5182	0.2468	0.4511	0.1712	0.5988	0.3726	0.3355	0.3355	0.3873	7.2624
A4	0.7290	0.5814	0.3082	0.8221	0.5246	0.5138	0.3699	0.6689	0.6305	0.1755	0.3742	0.3252	0.3266	0.4111	0.1371	0.1371	0.3600	7.3954
A5	0.6588	0.6904	0.4638	0.3855	0.7911	0.4611	0.3371	0.4814	0.4432	0.4417	0.2571	0.2088	0.0971	0.1371	0.1800	0.1800	0.2800	6.4941
A6	0.2724	0.2353	0.1553	0.1553	0.3301	0.6930	0.3755	0.3677	0.2906	0.0600	0.3355	0.4059	0.2111	0.2953	0.2171	0.2171	0.3951	5.0123
A7	0.4682	0.4682	0.5358	0.5059	0.4472	0.2486	0.7911	0.4830	0.4061	0.4029	0.3355	0.4029	0.2111	0.3726	0.1800	0.1800	0.3200	6.7593
A8	0.7290	0.6528	0.5438	0.6914	0.5652	0.5931	0.4875	0.8440	0.3306	0.2906	0.3000	0.3659	0.2906	0.2555	0.1800	0.1800	0.3600	7.6600
A9	0.5061	0.5061	0.3864	0.4279	0.2546	0.5181	0.2571	0.4459	0.8440	0.1342	0.4482	0.2866	0.3621	0.2953	0.2953	0.2953	0.3171	6.5804
A10	0.3881	0.3881	0.3881	0.1911	0.1771	0.3817	0.2971	0.3661	0.1342	0.8440	0.1755	0.3277	0.3637	0.4100	0.4108	0.4108	0.5106	6.1649
A11	0.5438	0.5053	0.5412	0.4682	0.3726	0.3973	0.1800	0.4814	0.6365	0.2481	0.7911	0.2111	0.4381	0.3726	0.2555	0.2555	0.2771	6.9755
A12	0.1955	0.1942	0.2755	0.1571	0.2600	0.3700	0.3346	0.4800	0.3661	0.6305	0.2600	0.8440	0.3661	0.3326	0.2955	0.2955	0.4000	6.0573
A13	0.5035	0.5412	0.4664	0.5040	0.1755	0.1913	0.1000	0.2111	0.3626	0.1342	0.3326	0.2111	0.8440	0.3742	0.4126	0.4126	0.3922	6.1690
A14	0.2711	0.1955	0.3511	0.2711	0.2953	0.2495	0.2953	0.4435	0.3661	0.3264	0.2953	0.3640	0.3277	0.7911	0.2555	0.2555	0.2800	5.6340
A15	0.3882	0.5053	0.4682	0.3479	0.3755	0.3314	0.2571	0.4432	0.3612	0.2852	0.4499	0.4011	0.4407	0.3717	0.7911	0.7911	0.3571	7.3661
A16	0.3506	0.5053	0.2711	0.3497	0.4153	0.2942	0.3353	0.4806	0.2906	0.3634	0.3755	0.4011	0.4835	0.4126	0.3329	0.3329	0.3171	6.3118
A17	0.1553	0.2724	0.2326	0.1924	0.2955	0.3311	0.3355	0.5185	0.3664	0.5959	0.4129	0.5559	0.2866	0.4100	0.2955	0.2955	0.7647	6.3168

Figure 2.12: Relation Matrix Aggregation

Step 07: Gathering the normalized direct matrix (O).

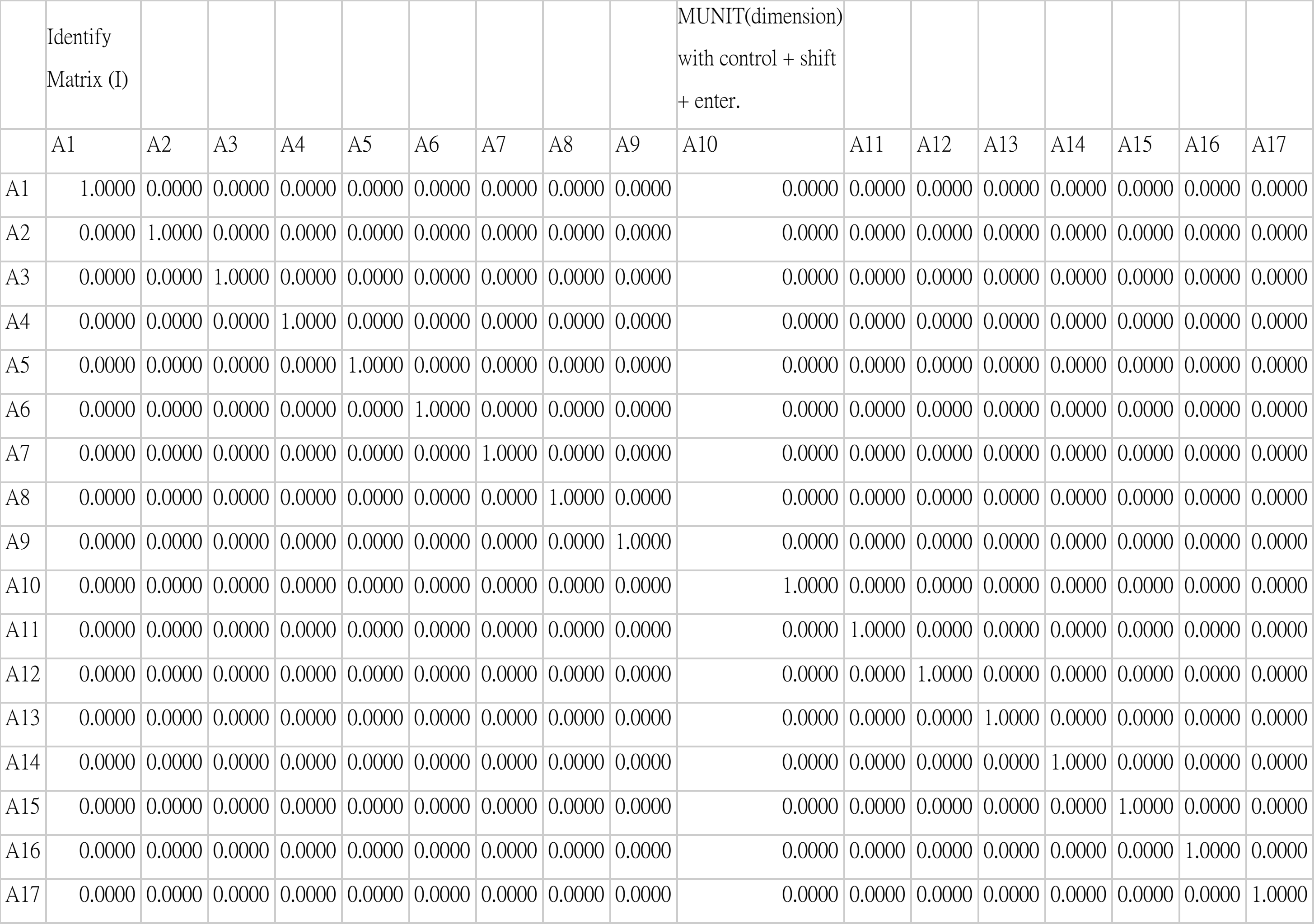
$$p = \frac{1}{\max\limits_{1 \le i \le n} \sum_{j=1}^{n} x_{ij}}, i, j = 1, 2, \cdots, n$$

$$O = p \times M$$

	Direct matrix (O)																
	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	A12	A13	A14	A15	A16	A17
A1	0.1073	0.0901	0.0602	0.0507	0.0490	0.0205	0.0392	0.0530	0.0873	0.0579	0.0484	0.0225	0.0375	0.0334	0.0287	0.0722	0.0412
A2	0.0507	0.1061	0.0762	0.0412	0.0589	0.0176	0.0339	0.0631	0.0880	0.0727	0.0641	0.0478	0.0474	0.0382	0.0330	0.0330	0.0670
A3	0.0762	0.0405	0.1073	0.0710	0.0732	0.0373	0.0388	0.0577	0.0677	0.0322	0.0589	0.0224	0.0782	0.0486	0.0438	0.0438	0.0506
A4	0.0952	0.0759	0.0402	0.1073	0.0685	0.0671	0.0483	0.0873	0.0823	0.0229	0.0488	0.0425	0.0426	0.0537	0.0179	0.0179	0.0470
A5	0.0860	0.0901	0.0605	0.0503	0.1033	0.0602	0.0440	0.0628	0.0579	0.0577	0.0336	0.0273	0.0127	0.0179	0.0235	0.0235	0.0366
A6	0.0356	0.0307	0.0203	0.0203	0.0431	0.0905	0.0490	0.0480	0.0379	0.0078	0.0438	0.0530	0.0276	0.0386	0.0283	0.0283	0.0516
A7	0.0611	0.0611	0.0699	0.0660	0.0584	0.0325	0.1033	0.0631	0.0530	0.0526	0.0438	0.0526	0.0276	0.0486	0.0235	0.0235	0.0418
A8	0.0952	0.0852	0.0710	0.0903	0.0738	0.0774	0.0636	0.1102	0.0432	0.0379	0.0392	0.0478	0.0379	0.0334	0.0235	0.0235	0.0470
A9	0.0661	0.0661	0.0504	0.0559	0.0332	0.0676	0.0336	0.0582	0.1102	0.0175	0.0585	0.0374	0.0473	0.0386	0.0386	0.0386	0.0414
A10	0.0507	0.0507	0.0507	0.0249	0.0231	0.0498	0.0388	0.0478	0.0175	0.1102	0.0229	0.0428	0.0475	0.0535	0.0536	0.0536	0.0667
A11	0.0710	0.0660	0.0706	0.0611	0.0486	0.0519	0.0235	0.0628	0.0831	0.0324	0.1033	0.0276	0.0572	0.0486	0.0334	0.0334	0.0362
A12	0.0255	0.0253	0.0360	0.0205	0.0339	0.0483	0.0437	0.0627	0.0478	0.0823	0.0339	0.1102	0.0478	0.0434	0.0386	0.0386	0.0522
A13	0.0657	0.0706	0.0609	0.0658	0.0229	0.0250	0.0131	0.0276	0.0473	0.0175	0.0434	0.0276	0.1102	0.0488	0.0539	0.0539	0.0512
A14	0.0354	0.0255	0.0458	0.0354	0.0386	0.0326	0.0386	0.0579	0.0478	0.0426	0.0386	0.0475	0.0428	0.1033	0.0334	0.0334	0.0366
A15	0.0507	0.0660	0.0611	0.0454	0.0490	0.0433	0.0336	0.0579	0.0472	0.0372	0.0587	0.0524	0.0575	0.0485	0.1033	0.1033	0.0466
A16	0.0458	0.0660	0.0354	0.0457	0.0542	0.0384	0.0438	0.0627	0.0379	0.0474	0.0490	0.0524	0.0631	0.0539	0.0435	0.0435	0.0414
A17	0.0203	0.0356	0.0304	0.0251	0.0386	0.0432	0.0438	0.0677	0.0478	0.0778	0.0539	0.0726	0.0374	0.0535	0.0386	0.0386	0.0998

Figure 2.13: Normalized direct matrix generation

Step 08: Establishing an identity matrix(I).



	Identify Matrix (I)									MUNIT(dimension) with control + shift + enter.							
	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	A12	A13	A14	A15	A16	A17
A1	1.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
A2	0.0000	1.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
A3	0.0000	0.0000	1.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
A4	0.0000	0.0000	0.0000	1.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
A5	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
A6	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
A7	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
A8	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
A9	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
A10	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
A11	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
A12	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000	0.0000	0.0000	0.0000	0.0000
A13	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000	0.0000	0.0000	0.0000
A14	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000	0.0000	0.0000
A15	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000	0.0000
A16	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000
A17	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000

Figure 2.14: Identity matrix establishment

Step 09: Employing identity matrix(I) minus the normalized direct matrix(O) and finding out the (I-O) matrix.

	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	A12	A13	A14	A15	A16	A17
A1	0.8927	(0.0901)	(0.0602)	(0.0507)	(0.0490)	(0.0205)	(0.0392)	(0.0530)	(0.0873)	(0.0579)	(0.0484)	(0.0225)	(0.0375)	(0.0334)	(0.0287)	(0.0722)	(0.0412)
A2	(0.0507)	0.8939	(0.0762)	(0.0412)	(0.0589)	(0.0176)	(0.0339)	(0.0631)	(0.0880)	(0.0727)	(0.0641)	(0.0478)	(0.0474)	(0.0382)	(0.0330)	(0.0330)	(0.0670)
A3	(0.0762)	(0.0405)	0.8927	(0.0710)	(0.0732)	(0.0373)	(0.0388)	(0.0577)	(0.0677)	(0.0322)	(0.0589)	(0.0224)	(0.0782)	(0.0486)	(0.0438)	(0.0438)	(0.0506)
A4	(0.0952)	(0.0759)	(0.0402)	0.8927	(0.0685)	(0.0671)	(0.0483)	(0.0873)	(0.0823)	(0.0229)	(0.0488)	(0.0425)	(0.0426)	(0.0537)	(0.0179)	(0.0179)	(0.0470)
A5	(0.0860)	(0.0901)	(0.0605)	(0.0503)	0.8967	(0.0602)	(0.0440)	(0.0628)	(0.0579)	(0.0577)	(0.0336)	(0.0273)	(0.0127)	(0.0179)	(0.0235)	(0.0235)	(0.0366)
A6	(0.0356)	(0.0307)	(0.0203)	(0.0203)	(0.0431)	0.9095	(0.0490)	(0.0480)	(0.0379)	(0.0078)	(0.0438)	(0.0530)	(0.0276)	(0.0386)	(0.0283)	(0.0283)	(0.0516)
A7	(0.0611)	(0.0611)	(0.0699)	(0.0660)	(0.0584)	(0.0325)	0.8967	(0.0631)	(0.0530)	(0.0526)	(0.0438)	(0.0526)	(0.0276)	(0.0486)	(0.0235)	(0.0235)	(0.0418)
A8	(0.0952)	(0.0852)	(0.0710)	(0.0903)	(0.0738)	(0.0774)	(0.0636)	0.8898	(0.0432)	(0.0379)	(0.0392)	(0.0478)	(0.0379)	(0.0334)	(0.0235)	(0.0235)	(0.0470)
A9	(0.0661)	(0.0661)	(0.0504)	(0.0559)	(0.0332)	(0.0676)	(0.0336)	(0.0582)	0.8898	(0.0175)	(0.0585)	(0.0374)	(0.0473)	(0.0386)	(0.0386)	(0.0386)	(0.0414)
A10	(0.0507)	(0.0507)	(0.0507)	(0.0249)	(0.0231)	(0.0498)	(0.0388)	(0.0478)	(0.0175)	0.8898	(0.0229)	(0.0428)	(0.0475)	(0.0535)	(0.0536)	(0.0536)	(0.0667)
A11	(0.0710)	(0.0660)	(0.0706)	(0.0611)	(0.0486)	(0.0519)	(0.0235)	(0.0628)	(0.0831)	(0.0324)	0.8967	(0.0276)	(0.0572)	(0.0486)	(0.0334)	(0.0334)	(0.0362)
A12	(0.0255)	(0.0253)	(0.0360)	(0.0205)	(0.0339)	(0.0483)	(0.0437)	(0.0627)	(0.0478)	(0.0823)	(0.0339)	0.8898	(0.0478)	(0.0434)	(0.0386)	(0.0386)	(0.0522)
A13	(0.0657)	(0.0706)	(0.0609)	(0.0658)	(0.0229)	(0.0250)	(0.0131)	(0.0276)	(0.0473)	(0.0175)	(0.0434)	(0.0276)	0.8898	(0.0488)	(0.0539)	(0.0539)	(0.0512)
A14	(0.0354)	(0.0255)	(0.0458)	(0.0354)	(0.0386)	(0.0326)	(0.0386)	(0.0579)	(0.0478)	(0.0426)	(0.0386)	(0.0475)	(0.0428)	0.8967	(0.0334)	(0.0334)	(0.0366)
A15	(0.0507)	(0.0660)	(0.0611)	(0.0454)	(0.0490)	(0.0433)	(0.0336)	(0.0579)	(0.0472)	(0.0372)	(0.0587)	(0.0524)	(0.0575)	(0.0485)	0.8967	(0.1033)	(0.0466)
A16	(0.0458)	(0.0660)	(0.0354)	(0.0457)	(0.0542)	(0.0384)	(0.0438)	(0.0627)	(0.0379)	(0.0474)	(0.0490)	(0.0524)	(0.0631)	(0.0539)	(0.0435)	0.9565	(0.0414)
A17	(0.0203)	(0.0356)	(0.0304)	(0.0251)	(0.0386)	(0.0432)	(0.0438)	(0.0677)	(0.0478)	(0.0778)	(0.0539)	(0.0726)	(0.0374)	(0.0535)	(0.0386)	(0.0386)	0.9002

Figure 2.15*:* (I-O) matrix finding

Step 10: Inversing the (I-O) matrix and finding out the $(I\text{-}O)^{-1}$ matrix.

	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	A12	A13	A14	A15	A16	A17
A1	1.543845635	0.531563187	0.452118467	0.4133189733	0.4058057084	0.3420277275	0.331201533	0.481692268	0.5116804474	0.3833170793	0.3921778039	0.3280160119	0.3669084418	0.3496214249	0.284436041	0.3515374064	0.3863726306
A2	0.500850764	1.562258657	0.4851095748	0.4170149991	0.4295693617	0.3538711486	0.3371667044	0.509689594	0.5276344543	0.4135333884	0.4221777235	0.3687528346	0.3913136505	0.3681565602	0.3004860295	0.3222548964	0.4289459589
A3	0.5359882384	0.500467968	1.520638303	0.4556483627	0.450367908	0.3776937753	0.3451683134	0.5078905293	0.5117168426	0.3679383813	0.4203367884	0.3421060192	0.4272223831	0.3822624216	0.3133729229	0.3366689972	0.4124520265
A4	0.5627360659	0.5454643955	0.4556021242	1.497790418	0.4517930344	0.41632593	0.3628509922	0.5484131327	0.5359736392	0.3651232863	0.4145037703	0.3708114597	0.3898330698	0.3909472648	0.2862538767	0.3107125127	0.4147847646
A5	0.4966394128	0.5046713393	0.4284705986	0.3897171864	1.442773919	0.3659441214	0.3207766211	0.4665639627	0.4543844717	0.3642247873	0.3539815818	0.3144576646	0.3161429563	0.3113944399	0.2610230571	0.2826088828	0.3609401254
A6	0.3342782274	0.3320710655	0.2893214503	0.269737032	0.2918876961	1.320514438	0.2562040638	0.3479647534	0.3292878939	0.2323020703	0.2830827754	0.2724444454	0.254508973	0.2602232089	0.2062574676	0.2207864626	0.2933004493
A7	0.4858986995	0.4874826626	0.4532508449	0.4216742597	0.4088687321	0.3488914124	1.394587279	0.4837571876	0.4638427654	0.3710179701	0.37727569	0.3546490349	0.3460965383	0.358880628	0.2710584507	0.2921774443	0.3787981094
A8	0.5814276342	0.573491929	0.505456545	0.4958674907	0.4744307996	0.4401026068	0.3928244353	1.590257737	0.5110720705	0.396754533	0.4182487766	0.3898392257	0.3991706203	0.3828369256	0.3033456408	0.328616683	0.4306435193
A9	0.4755838965	0.478843195	0.417855017	0.3983464245	0.368665417	0.3758999234	0.3090655371	0.4631453881	1.511634911	0.3176986849	0.3843473411	0.3279630039	0.3581948518	0.3373728553	0.2798022304	0.3004729038	0.3665581148
A10	0.4211622954	0.4255307843	0.3876951005	0.3337068688	0.3287326516	0.3300250517	0.2935660533	0.4185381141	0.3742150678	1.398520225	0.3173633303	0.3139389844	0.334963875	0.3324996482	0.2804160495	0.2987213544	0.370401502
A11	0.5108455239	0.5077842973	0.4659043264	0.4285925675	0.4082836282	0.3797656363	0.3159097624	0.4951737287	0.511512936	0.3537478987	1.452897219	0.3347531492	0.3907419276	0.3683796078	0.2907380748	0.3129413518	0.3826829579
A12	0.3858826122	0.3886429523	0.3632495196	0.3217335393	0.3318336437	0.3251084597	0.29333308	0.4257931883	0.3968020672	0.3625144971	0.3207724137	1.37932474	0.3273829353	0.3141636966	0.2582899655	0.2750618821	0.3471047833
A13	0.4505103017	0.4598624899	0.4080745943	0.3890753909	0.3370430031	0.3088073082	0.2683807888	0.4057253002	0.422388457	0.3013273578	0.349758207	0.2997105156	1.409966139	0.3329501775	0.2846682992	0.3042491794	0.3586898508
A14	0.377239446	0.3682042492	0.3551084836	0.3220568067	0.3206062007	0.2906463856	0.2720532395	0.3991927403	0.3790409241	0.2999034967	0.3093653832	0.2945129529	0.3048337548	1.360413745	0.2375851783	0.2539814302	0.3102607233
A15	0.5067613826	0.5285165646	0.4741392935	0.4276702427	0.4266785534	0.3856308337	0.3424491406	0.5119899585	0.4895203157	0.379532559	0.4231916874	0.3810839777	0.4097727888	0.386309733	1.380439231	0.4024649953	0.4122122901
A16	0.4353234251	0.4601515922	0.3870916434	0.3715749357	0.3755269275	0.3304505627	0.3081242792	0.4498274733	0.4149818917	0.340918773	0.3575313932	0.3322521389	0.3609587397	0.3412771258	0.2755091035	1.294429905	0.3533982182
A17	0.3979408808	0.417545765	0.3735564948	0.3415877918	0.3519855035	0.3334614151	0.3055708257	0.4498223841	0.4150113775	0.3716045653	0.3569388053	0.3533155336	0.3291745119	0.3382774234	0.2681931301	0.2854891446	1.410962766

Figure 2.16*:* $(I\text{-}O)^{-1}$ matrix finding

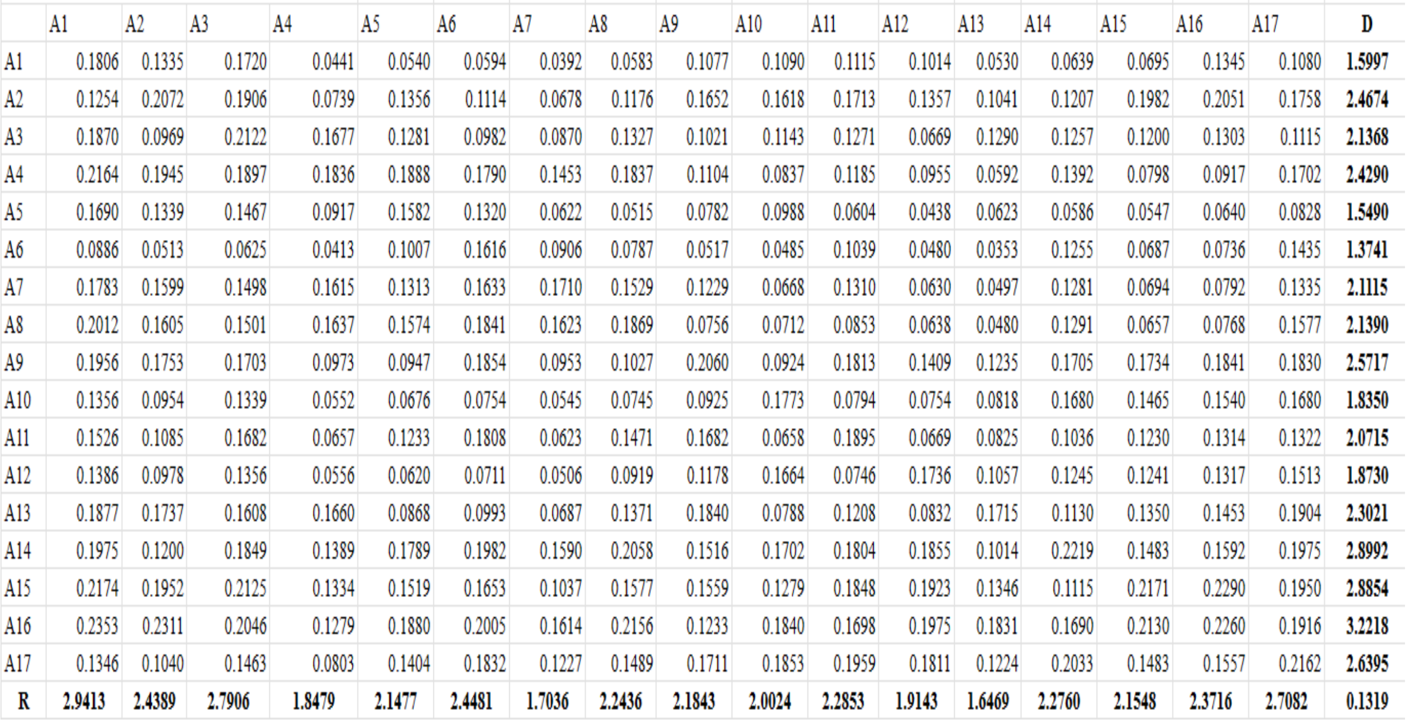
Step 11: Multiplying the (I-O)-1 matrix and O matrix to obtain the total relation matrix(S).

	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	A12	A13	A14	A15	A16	A17	**D**
A1	0.5438	0.5316	0.4521	0.4133	0.4058	0.3420	0.3312	0.4817	0.5117	0.3833	0.3922	0.3280	0.3669	0.3496	0.2844	0.3515	0.3864	**6.8556**
A2	0.5009	0.5623	0.4851	0.4170	0.4296	0.3539	0.3372	0.5097	0.5276	0.4135	0.4222	0.3688	0.3913	0.3682	0.3005	0.3223	0.4289	**7.1388**
A3	0.5360	0.5005	0.5206	0.4556	0.4504	0.3777	0.3452	0.5079	0.5117	0.3679	0.4203	0.3421	0.4272	0.3823	0.3134	0.3367	0.4125	**7.2079**
A4	0.5627	0.5455	0.4556	0.4978	0.4518	0.4163	0.3629	0.5484	0.5360	0.3651	0.4145	0.3708	0.3898	0.3909	0.2863	0.3107	0.4148	**7.3199**
A5	0.4966	0.5047	0.4285	0.3897	0.4428	0.3659	0.3208	0.4666	0.4544	0.3642	0.3540	0.3145	0.3161	0.3114	0.2610	0.2826	0.3609	**6.4347**
A6	0.3343	0.3321	0.2893	0.2697	0.2919	0.3205	0.2562	0.3480	0.3293	0.2323	0.2831	0.2724	0.2545	0.2602	0.2063	0.2208	0.2933	**4.7942**
A7	0.4859	0.4875	0.4533	0.4217	0.4089	0.3489	0.3946	0.4838	0.4638	0.3710	0.3773	0.3546	0.3461	0.3589	0.2711	0.2922	0.3788	**6.6982**
A8	0.5814	0.5735	0.5055	0.4959	0.4744	0.4401	0.3928	0.5903	0.5111	0.3968	0.4182	0.3898	0.3992	0.3828	0.3033	0.3286	0.4306	**7.6144**
A9	0.4756	0.4788	0.4179	0.3983	0.3687	0.3759	0.3091	0.4631	0.5116	0.3177	0.3843	0.3280	0.3582	0.3374	0.2798	0.3005	0.3666	**6.4714**
A10	0.4212	0.4255	0.3877	0.3337	0.3287	0.3300	0.2936	0.4185	0.3742	0.3985	0.3174	0.3139	0.3350	0.3325	0.2804	0.2987	0.3704	**5.9600**
A11	0.5108	0.5078	0.4659	0.4286	0.4083	0.3798	0.3159	0.4952	0.5115	0.3537	0.4529	0.3348	0.3907	0.3684	0.2907	0.3129	0.3827	**6.9107**
A12	0.3859	0.3886	0.3632	0.3217	0.3318	0.3251	0.2933	0.4258	0.3968	0.3625	0.3208	0.3793	0.3274	0.3142	0.2583	0.2751	0.3471	**5.8170**
A13	0.4505	0.4599	0.4081	0.3891	0.3370	0.3088	0.2684	0.4057	0.4224	0.3013	0.3498	0.2997	0.4100	0.3330	0.2847	0.3042	0.3587	**6.0912**
A14	0.3772	0.3682	0.3551	0.3221	0.3206	0.2906	0.2721	0.3992	0.3790	0.2999	0.3094	0.2945	0.3048	0.3604	0.2376	0.2540	0.3103	**5.4550**
A15	0.5068	0.5285	0.4741	0.4277	0.4267	0.3856	0.3424	0.5120	0.4895	0.3795	0.4232	0.3811	0.4098	0.3863	0.3804	0.4025	0.4122	**7.2684**
A16	0.4353	0.4602	0.3871	0.3716	0.3755	0.3305	0.3081	0.4498	0.4150	0.3409	0.3575	0.3323	0.3610	0.3413	0.2755	0.2944	0.3534	**6.1893**
A17	0.3979	0.4175	0.3736	0.3416	0.3520	0.3335	0.3056	0.4498	0.4150	0.3716	0.3569	0.3533	0.3292	0.3383	0.2682	0.2855	0.4110	**6.1004**
R	**8.0029**	**8.0726**	**7.2226**	**6.6951**	**6.6049**	**6.0252**	**5.4492**	**7.9554**	**7.7607**	**6.0200**	**6.3540**	**5.7579**	**6.1172**	**5.9160**	**4.7819**	**5.1732**	**6.4185**	**0.3818**

Figure 2.17*:* Finding the relation matrix

Step 12: Calculating the summation of rows(D) and summation of columns(R).

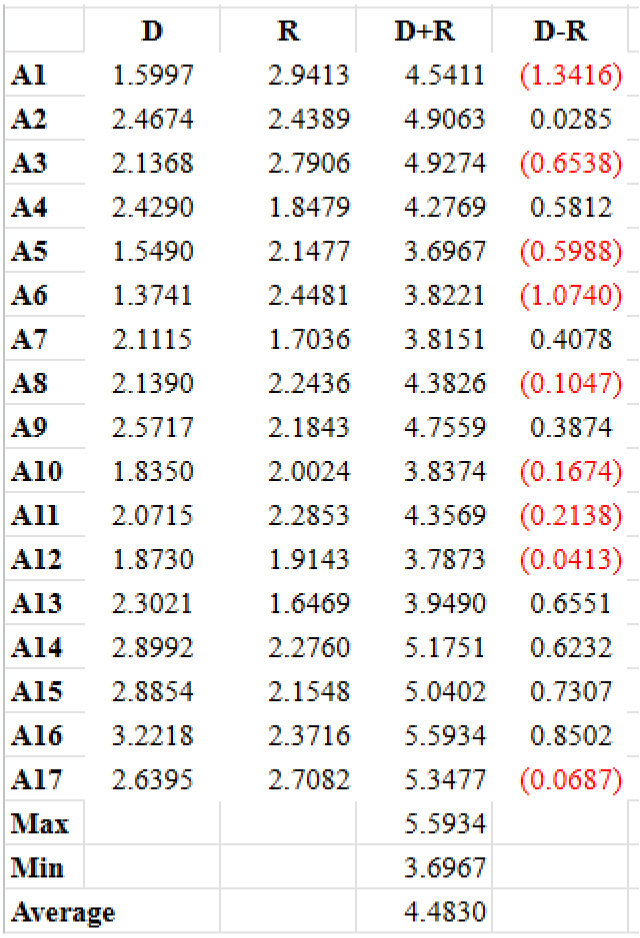
$$R = \left[\sum_{j-1}^{n} s_{ij}\right]_{1\times n} = [s_j]_{1\times n} \qquad D = \left[\sum_{i-1}^{n} s_{ij}\right]_{n\times 1} = [s_i]_{n\times 1}$$



	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	A12	A13	A14	A15	A16	A17	D
A1	0.1806	0.1335	0.1720	0.0441	0.0540	0.0594	0.0392	0.0583	0.1077	0.1090	0.1115	0.1014	0.0530	0.0639	0.0695	0.1345	0.1080	**1.5997**
A2	0.1254	0.2072	0.1906	0.0739	0.1356	0.1114	0.0678	0.1176	0.1652	0.1618	0.1713	0.1357	0.1041	0.1207	0.1982	0.2051	0.1758	**2.4674**
A3	0.1870	0.0969	0.2122	0.1677	0.1281	0.0982	0.0870	0.1327	0.1021	0.1143	0.1271	0.0669	0.1290	0.1257	0.1200	0.1303	0.1115	**2.1368**
A4	0.2164	0.1945	0.1897	0.1836	0.1888	0.1790	0.1453	0.1837	0.1104	0.0837	0.1185	0.0955	0.0592	0.1392	0.0798	0.0917	0.1702	**2.4290**
A5	0.1690	0.1339	0.1467	0.0917	0.1582	0.1320	0.0622	0.0515	0.0782	0.0988	0.0604	0.0438	0.0623	0.0586	0.0547	0.0640	0.0828	**1.5490**
A6	0.0886	0.0513	0.0625	0.0413	0.1007	0.1616	0.0906	0.0787	0.0517	0.0485	0.1039	0.0480	0.0353	0.1255	0.0687	0.0736	0.1435	**1.3741**
A7	0.1783	0.1599	0.1498	0.1615	0.1313	0.1633	0.1710	0.1529	0.1229	0.0668	0.1310	0.0630	0.0497	0.1281	0.0694	0.0792	0.1335	**2.1115**
A8	0.2012	0.1605	0.1501	0.1637	0.1574	0.1841	0.1623	0.1869	0.0756	0.0712	0.0853	0.0638	0.0480	0.1291	0.0657	0.0768	0.1577	**2.1390**
A9	0.1956	0.1753	0.1703	0.0973	0.0947	0.1854	0.0953	0.1027	0.2060	0.0924	0.1813	0.1409	0.1235	0.1705	0.1734	0.1841	0.1830	**2.5717**
A10	0.1356	0.0954	0.1339	0.0552	0.0676	0.0754	0.0545	0.0745	0.0925	0.1773	0.0794	0.0754	0.0818	0.1680	0.1465	0.1540	0.1680	**1.8350**
A11	0.1526	0.1085	0.1682	0.0657	0.1233	0.1808	0.0623	0.1471	0.1682	0.0658	0.1895	0.0669	0.0825	0.1036	0.1230	0.1314	0.1322	**2.0715**
A12	0.1386	0.0978	0.1356	0.0556	0.0620	0.0711	0.0506	0.0919	0.1178	0.1664	0.0746	0.1736	0.1057	0.1245	0.1241	0.1317	0.1513	**1.8730**
A13	0.1877	0.1737	0.1608	0.1660	0.0868	0.0993	0.0687	0.1371	0.1840	0.0788	0.1208	0.0832	0.1715	0.1130	0.1350	0.1453	0.1904	**2.3021**
A14	0.1975	0.1200	0.1849	0.1389	0.1789	0.1982	0.1590	0.2058	0.1516	0.1702	0.1804	0.1855	0.1014	0.2219	0.1483	0.1592	0.1975	**2.8992**
A15	0.2174	0.1952	0.2125	0.1334	0.1519	0.1653	0.1037	0.1577	0.1559	0.1279	0.1848	0.1923	0.1346	0.1115	0.2171	0.2290	0.1950	**2.8854**
A16	0.2353	0.2311	0.2046	0.1279	0.1880	0.2005	0.1614	0.2156	0.1233	0.1840	0.1698	0.1975	0.1831	0.1690	0.2130	0.2260	0.1916	**3.2218**
A17	0.1346	0.1040	0.1463	0.0803	0.1404	0.1832	0.1227	0.1489	0.1711	0.1853	0.1959	0.1811	0.1224	0.2033	0.1483	0.1557	0.2162	**2.6395**
R	**2.9413**	**2.4389**	**2.7906**	**1.8479**	**2.1477**	**2.4481**	**1.7036**	**2.2436**	**2.1843**	**2.0024**	**2.2853**	**1.9143**	**1.6469**	**2.2760**	**2.1548**	**2.3716**	**2.7082**	**0.1319**

Figure 2.18: Finding D and R matrix

Step 13: Calculating the (D+R) and (D-R) for mapping the cause and effect diagram.



	D	R	D+R	D-R
A1	1.5997	2.9413	4.5411	(1.3416)
A2	2.4674	2.4389	4.9063	0.0285
A3	2.1368	2.7906	4.9274	(0.6538)
A4	2.4290	1.8479	4.2769	0.5812
A5	1.5490	2.1477	3.6967	(0.5988)
A6	1.3741	2.4481	3.8221	(1.0740)
A7	2.1115	1.7036	3.8151	0.4078
A8	2.1390	2.2436	4.3826	(0.1047)
A9	2.5717	2.1843	4.7559	0.3874
A10	1.8350	2.0024	3.8374	(0.1674)
A11	2.0715	2.2853	4.3569	(0.2138)
A12	1.8730	1.9143	3.7873	(0.0413)
A13	2.3021	1.6469	3.9490	0.6551
A14	2.8992	2.2760	5.1751	0.6232
A15	2.8854	2.1548	5.0402	0.7307
A16	3.2218	2.3716	5.5934	0.8502
A17	2.6395	2.7082	5.3477	(0.0687)
Max			5.5934	
Min			3.6967	
Average			4.4830	

Figure 2.19: Finding (D+R), (D-R) matrix and plotting (D-R) on graph

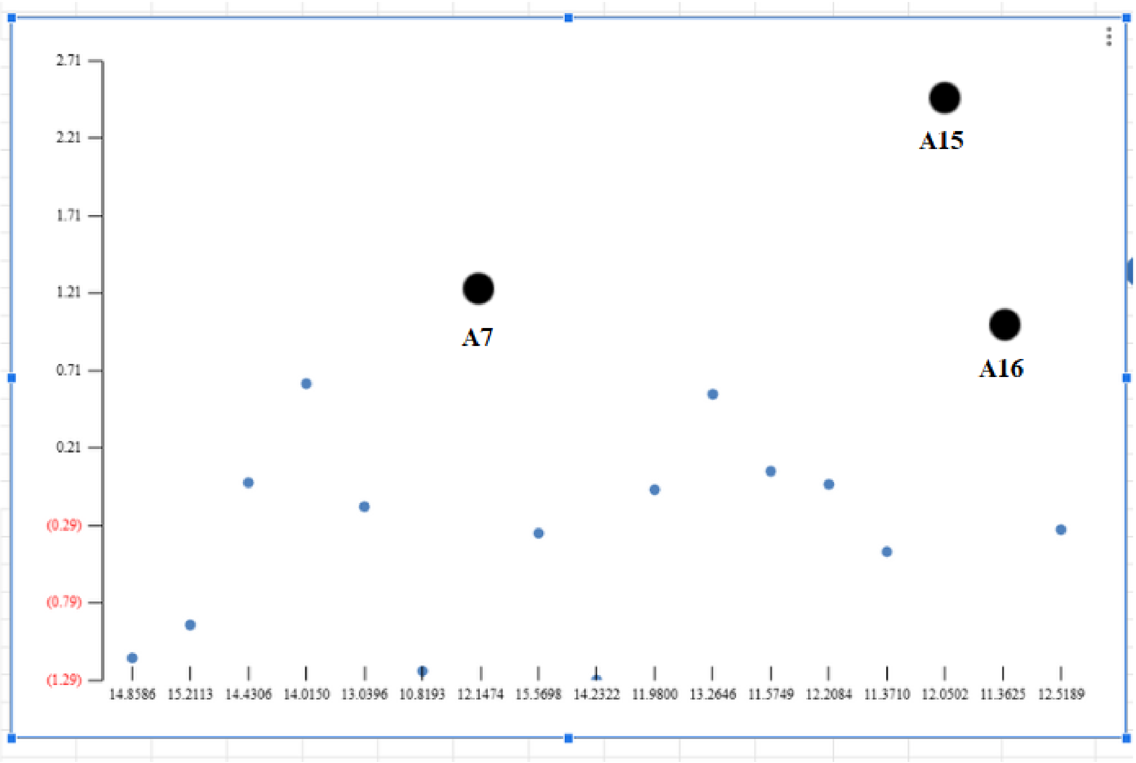


Figure 2.20: Key aspects identified

CHAPTER 04: RESULTS AND DISCUSSION

4.1 Utilization of Fuzzy DEMATEL in the Ceramic Industry of Bangladesh

This research looked at sustainable supply chain management in Bangladesh's ceramic industry using the Fuzzy Decision Making Trial and Evaluation Laboratory (DEMATEL) approach. Based on the created cause-and-effect diagram, the main goal of the findings is to distinguish between causes and effects inside the system.

4.2 Identification of Causal Factors and Consequences

Many basic components that were characterized as causes by their favorable values in the cause-and-effect diagram were found through study. To alter the system, these causes are essential elements that may be changed or managed. On the other hand, components that are shown on the figure below the zero point are categorized as repercussions. These consequences are a direct consequence of the causes and are not modifiable in isolation. Rather, they are affected by changes in the causative elements.

Key Causes Identified:

Collaborative Sustainable Initiatives(A15): Through Collaborative Sustainable Initiatives, government agencies, NGOs, suppliers, and ceramic producers work together to improve sustainability. These include partnerships in research and development, sustainability goals, and environmental projects.

A more integrated approach to sustainability that incorporates a variety of concepts and resources is facilitated by collaboration. In this cooperative environment, innovation and knowledge exchange promote more effective and efficient sustainable practices. Cooperation may also increase the sustainability of the supply chain by establishing industry-wide norms and procedures. Cooperation is essential because complex sustainability concerns need collaborative responses.

- **Importance:**By combining resources, exchanging best practices, and stimulating creativity, these efforts can promote the adoption of sustainability measures more widely and effectively.
- **Examples:** Industry-wide programs, joint ventures, and partnerships with environmental organizations or government bodies to promote sustainability.

- **Impact:** increases the exchange of knowledge, cuts down on redundant work, and uses group power to push for laws and regulations that are in the best interests of everyone.

Water Resource Management(A7): Water resource management is concerned with the effective and sustainable use of water at every stage of the manufacturing process, from the processing of raw materials to the finished goods. This includes the application of cutting-edge water-saving technology, water recycling and reuse during the manufacturing cycle, and efficient wastewater treatment prior to discharge.

Since minimizing the environmental effect of ceramic manufacture requires appropriate water management methods, the influence on the sustainable supply chain is significant. The industry may limit its influence on nearby water supplies and drastically reduce its operational expenses by managing water consumption. A balance between industrial demands and ecological preservation is promoted by efficient water resource management, which guarantees that sustainability is ingrained at every level of production. This strategy improves the industry's standing for environmental stewardship while also aiding in regulatory compliance. Additionally, innovative approaches to resource management and process efficiency can result from sustainable water practices, enhancing the supply chain's overall resilience and sustainability.

- **Importance:** Water is a vital resource utilized in the production of clay and cooling processes, among other steps of ceramic manufacture. Both operating expenses and the environmental impact may be greatly decreased by effective management.
- **Examples:** Implementation of closed-loop water systems, water recycling technologies, and strategies to minimize water wastage.
- **Impact:** minimizes the impact on the environment, guarantees adherence to water usage laws, and cuts the price of water procurement and waste treatment.

Sustainable Industry Resilience(A16): An industry that can be sustained for an extended length of time without endangering the environment or exhausting natural resources. The ability of the ceramics sector to withstand and adapt to various environmental, economic, and social challenges while maintaining sustainable practices is known as resilience. This includes the industry's capacity to recover from shocks like market turbulence or natural disasters, as well as to adapt to long-term changes like shifting consumer preferences or shifting regulatory environments.

The resilience of the industry, which directly affects the stability and uninterrupted flow of products and services, has a substantial impact on the sustainable supply chain. An industry that is robust can better handle disruptions, ensuring that the supply chain runs smoothly. Stability is necessary for a system to be viable over the long run because it allows social and environmental standards to be maintained even in adverse situations. Furthermore, a thriving industry may produce fresh, innovative approaches to sustainability issues, which will promote continuous improvements in sustainable supply chain processes.

- **Importance:** Establishing resilience helps the sector remain viable and stable over the long run by reducing the risks brought on by a lack of resources, shifting laws, and volatile markets.
- **Examples:** Diversifying supply sources, adopting flexible and sustainable production methods, and developing contingency plans for environmental disruptions.
- **Impact:** increases the industry's resilience to unfavorable circumstances, preserving its competitiveness and productivity.

Key Effects Identified:

Sustainable Raw Material Acquisition(A9): Sustainable raw material acquisition refers to the procurement of raw materials with an eye toward reducing environmental impact and enhancing ecosystem health over the long term. Using recycled materials, guaranteeing traceability and ethical sourcing, and collaborating with suppliers who follow sustainable mining and harvesting methods are all examples of this technique.

Since sustainable raw material acquisition provides supply continuity and dependability while safeguarding natural resources, it has a significant influence on the sustainable supply chain. The ceramics sector can lower its carbon footprint, prevent habitat damage, and slow the depletion of non-renewable resources by giving priority to materials obtained responsibly. This strategy encourages a supply chain that is robust and flexible in the face of environmental difficulties. In addition, it improves the industry's standing and satisfies customer demand for environmentally friendly goods. Sustainable sourcing techniques promote innovation in the handling and use of materials, which results in more productive manufacturing processes and an all-around stronger, more sustainable supply chain.

- **Benefits:** Ensures a stable supply of materials, reduces environmental degradation, and enhances the industry's reputation for environmental stewardship.
- **Examples:** Using recycled materials, sourcing from suppliers with sustainable practices, and ensuring traceability and ethical procurement.
- **Impact:** Promotes long-term resource availability, reduces supply chain disruptions, and meets the increasing demand from consumers and regulators for sustainable products.

Greenhouse Gas Emissions Assessment(A6): The Greenhouse Gas Emissions Assessment calculates and evaluates emissions from the supply chain. Transportation, energy consumption, and manufacturing emissions are on the list. Accurate evaluation is necessary to find strategies for reducing carbon footprint.

To ensure the sustainability of the environment, greenhouse gas emissions must be evaluated and controlled. It assists businesses in locating emission-free zones and implementing environmentally friendly procedures and equipment. This lessens climate change and brings the business into compliance with international environmental standards and goals. Reducing carbon emissions may improve brand recognition and draw in environmentally sensitive clients.

- **Benefits:** Reducing emissions lowers the environmental footprint, improves compliance with environmental regulations, and reduces potential costs associated with carbon taxes and penalties.
- **Examples:** Implementing energy-efficient technologies, switching to renewable energy sources, and optimizing production processes to reduce waste.
- **Impact:** Contributes to global efforts to combat climate change, improves air quality, and enhances the industry's public image as an environmentally responsible sector.

Cost Optimization(A1): In order to effectively manage and lower manufacturing, logistics, and supply chain costs while maintaining or enhancing sustainability, the sustainable supply chain employs cost optimization. This includes waste minimization, resource optimization, and operational effectiveness.

Effective cost control is necessary for the supply chain to be economically sustainable. Without sacrificing their commitment to social responsibility and the environment, cost optimization enables businesses to invest in sustainable technology, use resources more wisely, and provide competitive pricing. Using sustainable practices and staying afloat are made easier for enterprises by cost efficiency.

- **Benefits:** Enhances profitability, improves competitiveness, and allows for reinvestment into further sustainable practices.
- **Examples:** Adopting lean manufacturing techniques, reducing waste, improving energy efficiency, and streamlining supply chain processes.
- **Impact:** Lowers overall production costs, increases margins, and provides financial stability and flexibility for the industry to invest in innovative sustainable practices.

4.3 Analysis of the causal connection between events and their consequences

The interconnected structure of the supply chain in the ceramic industry is demonstrated by the implementation of the Fuzzy DEMATEL method. The causes that have been emphasized are important elements that may be used to encourage sustainable behaviors. When they are properly maintained and optimized, the results may be significantly improved and are used as gauges of the overall health and resilience of the supply chain.

The results underscore the need of placing a deliberate focus on the elements that have been identified. By concentrating on these particular areas, Bangladesh's ceramic industry should expect a positive shift in its results, leading to a more productive and ecologically friendly supply chain.

CHAPTER 05: FUTURE RECOMMENDATION

As part of our continuous efforts to improve the sustainability of the ceramics sector, we suggest carrying out an extensive Life Cycle Analysis (LCA) to corroborate and improve our conclusions. Future research will make use of OpenLCA, an effective technique for assessing environmental impacts, to offer in-depth analyses of the industry's environmental performance. The Life Cycle Assessment (LCA) will need broad access to industry data, encompassing details on the procurement of raw materials, production procedures, energy usage, emissions, and waste handling. Our Life Cycle Analysis (LCA) procedures are based on the publication "Ceramic Cup vs. Paper Cup" (Martin et al., 2018).

5.1 Goal and Scope Definition

Goal: Describe the objective of the Life Cycle Assessment (LCA), which is to evaluate the environmental effects linked to the supply chain of the ceramic sector and confirm the efficacy of our suggested sustainable practices.

Range: Establish the limits of the system for the extraction of raw materials, production procedures, transportation, use, and disposal at the end of the system's life. Determine the functional unit (one ceramic cup, for example) and choose pertinent effect categories (resource depletion, water consumption, and potential for global warming).

5.2 Inventory Analysis

Data Collection: Throughout the life cycle stages, collect comprehensive data on all inputs (raw materials, energy, water) and outputs (waste, emissions). To obtain precise and thorough data for this phase, industry partners must work together.

Data Compilation: Put the gathered information into a structured manner that can be entered into the OpenLCA program. Make sure the data is representative and of high quality.

5.3 Impact Assessment

Modeling:Enter the inventory data and simulate the life cycle stages using OpenLCA. Use suitable life cycle assessment (LCA) techniques, such as CML and ReCiPe, to measure the environmental effects.

Impact Categories: Evaluate the effects on a few chosen categories, including toxicity, water usage, energy use, and climate change. Analyze possible compromises between various effect categories.

5.4 Interpretation of Results

Analysis: Analyze the findings to pinpoint important environmental hotspots and areas in need of development. Examine scenarios that apply our suggested sustainable practices against the baseline scenario, which consists of the present ways.

Validation: Show how our ideas reduce environmental consequences in the predicted scenarios to validate their efficacy.

5.5 Reporting and Improvement

Documentation: Create a thorough report that details the LCA process, data sources, presumptions, outcomes, and interpretations..

Recommendations: Provide actionable recommendations based on the LCA findings to further enhance sustainability practices within the ceramic industry.

Continuous Improvement: Use the insights gained from the LCA to drive continuous improvement initiatives, encouraging the industry to adopt more sustainable practices and technologies.

5.6 Conclusion

This study represents a significant step forward in the understanding and enhancement of sustainable supply chain management in the ceramic sector of Bangladesh. Our study successfully identified critical causal factors—Sustainable Industry Resilience, Collaborative Sustainable Initiatives, and Supplier Partnership Development—as well as their effects, which include Competitive Edge in the Market, Cost Optimization, and Greenhouse Gas Emissions Assessment. This was accomplished by utilizing the Fuzzy DEMATEL method. These results provide a critical knowledge of the complex interplay of variables that result in corporate sustainability.

Precisely identifying these causes and consequences has important practical implications for the business and is not just an academic matter. Industry participants may increase market competitiveness and operational efficiency by putting in place customized programs that address root problems and advance sustainability. The study highlights how important it is to take a holistic strategy that incorporates social and economic objectives with environmental concerns.

Our study does, however, have a number of shortcomings. Although it provides insightful information, the Fuzzy DEMATEL study's use of a single expert's perspective also suggests the need for a more complete perspective. Therefore, it is essential that future research involve a wider range of experts in order to improve and validate the findings. Moreover, the application of Flexsim software in subsequent studies will provide a practical validation of our theoretical claims, offering a more comprehensive understanding of the impacts of various sustainability initiatives.

Notwithstanding current environmental challenges, Bangladesh's ceramic industry has the potential to become a model of sustainability. This research offers a well-defined strategy that integrates ecological duties with financial demands, therefore streamlining the procedure for accomplishing this kind of change. The industry must constantly advance and change to accommodate new knowledge and technological advancements if it is to experience sustained growth. This study contributes to a growing body of knowledge that benefits Bangladesh's ceramic sector as well as other businesses hoping to accomplish sustainable supply chain management in poor countries. If we are able to accomplish these tasks, it will be an outstanding achievement and surely it will create a buzz among the industries. Because of this, all the industries will have a more position approach and will try to implement supply chain practices in their field.

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