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# **Choosing Supplier by Using Multi-Criteria Decision Analysis (MCDA)**

A Case Study on Readymade Garments Industry in Bangladesh

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**ABSTRACT:**

This study explores the issue of supplier selection in a dynamic and competitive textile manufacturing sector, focusing on Monno Fabrics Ltd in Bangladesh. Acknowledging the strategic nature of procurement in supply chain management, the research identifies a key gap within the organisation: the lack of a systematic, transparent and multi-criteria approach for supplier evaluation and selection. Historically, supplier selection at the firm has been based on informal decision-making, price, and interpersonal relationships, resulting in inconsistencies and potential inefficiencies. The study introduces a Multi-Criteria Decision Analysis (MCDA) approach to address this, incorporating the Analytic Hierarchy Process (AHP) and the Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS). The research employs a deductive and pragmatic research design, with a single embedded case study approach. Data were gathered primarily from structured pairwise comparisons and interviews with experienced procurement managers and secondarily from procurement records to assess supplier performance. We identified a list of ten criteria for supplier evaluation via a literature review and expert review process, which included traditional criteria, such as quality, delivery performance, and cost, as well as more current issues, such as sustainability, risk, and supplier relationships. The AHP approach was used to calculate the relative weighting (weights) of the criteria, with consistency verified through the consistency ratio test. The findings showed that quality and delivery performance are the key criteria in supplier selection, followed by cost criteria. However, the current situation at the company has shown that sustainability and relational criteria have a comparatively lower weight. The TOPSIS approach was then applied to evaluate and rank six suppliers in terms of the weighted criteria. The results highlight the utility of the hybrid AHP-TOPSIS approach in generating a transparent, logical and replicable supplier ranking process. In order to ensure the validity of the findings, a sensitivity analysis was performed by altering the importance of criteria. This analysis revealed that some criteria have a considerable impact on the rankings, but the model is fairly robust across different weight sets. The research is relevant both theoretically and practically. Theoretically, it helps fill a gap in the use of MCDA approaches in the Bangladeshi textile industry. In practice, it offers Monno Fabrics Ltd. a decision-making framework that improves clarity, consistency and alignment of supplier procurement decisions. The study further provides some practical insights into incorporating MCDA into organisational practices, particularly in terms of stakeholder participation and ongoing assessment. More broadly, the thesis underscores the benefits of structured and analytical decision-making in supplier procurement and shows the value of MCDA models in improving supply chain efficiency and robustness in manufacturing settings.

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**KEYWORDS:** Supplier Selection; MCDA; AHP; TOPSIS; Supply Chain Management; Textile Industry; Bangladesh.

## Contents

1	Introduction	6
1.1	Background and Motivation	7
1.2	Research Problem	8
1.3	Research Questions and Objectives	9
1.4	Scope and Limitations	10
1.5	Structure of the Thesis	11
2	Literature Review	13
2.1	Supply Chain Management and the Strategic Role of Procurement	13
2.2	Supplier Selection: Concept, Significance, and Evolution	14
2.3	Supplier Evaluation Criteria	15
2.3.1	Classical Criteria Frameworks	16
2.3.2	Sustainability and Risk Criteria	16
2.4	Multi-Criteria Decision Analysis: An Overview	17
2.5	Analytic Hierarchy Process (AHP)	18
2.6	TOPSIS: Technique for Order of Preference by Similarity to Ideal Solution	19
2.7	Hybrid MCDA Approaches and Sensitivity Analysis	20
2.8	MCDA Applications in Textile and Manufacturing Procurement	21
2.9	Theoretical Framework and Research Gap	22
03	Methodology	26
3.1	Introduction	26
3.2	Research Philosophy	26
3.3	Research Approach	27
3.4	Research Strategy	28
3.5	Research Design Overview	29
3.6	Data Collection	29
3.6.1	Primary Data: Expert Elicitation for AHP Criteria Weighting	30

3.6.2 Secondary Data: Procurement Records for TOPSIS Input	31
3.7 Criteria Selection and Operationalisation	32
3.8 Analytic Hierarchy Process (AHP): Criteria Weighting	34
3.8.1 Hierarchical Problem Structure	34
3.8.2 Pairwise Comparison and the Saaty Scale	34
3.8.3 Priority Vector Calculation	35
3.8.4 Consistency Assessment	36
3.9 TOPSIS: Supplier Ranking	37
Step 1: Construct the Decision Matrix	37
Step 2: Normalise the Decision Matrix	37
Step 3: Construct the Weighted Normalised Decision Matrix	38
Step 4: Determine Ideal Solutions	38
Step 5: Calculate Euclidean Distances	38
Step 6: Calculate Relative Closeness Coefficient and Rank	38
3.10 Supplier Sample Selection	39
3.11 Sensitivity Analysis	40
3.12 Research Quality: Validity, Reliability, and Rigour	42
3.12.1 Internal Validity	42
3.12.2 Construct Validity	42
3.12.3 Reliability	43
3.12.4 External Validity and Generalisability	43
3.13 Ethical Considerations	44
3.14 Chapter Summary	45
4 Results	46
4.1 AHP Criteria Weighting: Expert Elicitation Results	46
4.1.1 Consistency Assessment	46
4.1.2 Derived Criteria Weights	47
4.2 Qualitative Findings: Semi-Structured Interview Results	49
4.3 TOPSIS Supplier Ranking Results	51
4.3.1 Decision Matrix and Performance Scores	51

4.3.2 TOPSIS Closeness Coefficients and Supplier Rankings	52
4.4 Sensitivity Analysis Results	53
4.5 Summary of Results	55
5 Discussion and Conclusion	56
5.1 Discussion of Principal Findings	56
5.1.1 Criteria Prioritisation: Convergence with and Divergence from the Literature	56
5.1.2 Supplier Rankings and Their Strategic Implications	57
5.1.3 Sensitivity Analysis: Implications for Procurement Decision Robustness	58
5.2 Theoretical Contributions	59
5.3 Practical Recommendations	60
5.4 Limitations and Directions for Future Research	62
5.5 Conclusion	64
References	66

## Tables

<a href="#">Table 1</a> Summary of key studies on supplier selection and MCDA (author's compilation).	26
Table 3.1 Research design summary	31
Table 3.2 Supplier evaluation criteria: definitions and sources.	34
Table 3.3 Saaty's fundamental scale for pairwise comparisons (Saaty, 1980).	37
Table 3.4 Random Index (RI) values for matrix sizes $n = 1$ to 10 (Saaty, 1980).	38
Table 3.5 Supplier sample for MCDA evaluation (anonymised ).	41
Table 3.6 Sensitivity analysis scenarios.	43
Table 4.1 AHP consistency assessment results	49
Table 4.2 AHP-derived criteria weights (normalised eigenvector).	49
Table 4.3 Decision matrix: supplier performance scores across ten criteria	53
Table 4.4 TOPSIS results	54
Table 4.5 Sensitivity analysis results: supplier rank positions across seven weighting scenarios.	55

## 1 Introduction

In the contemporary competitive and globalized market, the supply chain management has become one of the pillars of sustainable organizational performance. The procurement is the core of supply chain management and in procurement, supplier selection is the most strategically central activity. The choice on suppliers to deal with will determine the quality of the products being offered, consistency of deliveries, cost of business, and finally, the competitive position of the company. In manufacturing businesses that deal with resource intensive industries like the textile and garments industry, the stakes of the selection of the supplier are very high. The quality of raw materials, the lead-time adherence, and the financial stability of their suppliers each can either lead to the achievement of the production goals and the fulfilment of customer demands (Dickson, 1966; Deng et al., 2014).

In spite of the recognized significance of supplier selection, most organizations have been using informal, experience-based, or single-criteria approaches to procurement in making decisions. These methods are inadequate when a company has to consider suppliers on a multidimensional basis, typically in multiple dimensions which are usually in conflict with each other such as a cheap supplier can deliver a poor performance, a reliable supplier can charge high prices. These trade-offs make it inherently complex, which requires systematic, transparent and reproducible decision-making systems capable of incorporating quantitative and expert data (Ho et al., 2010).

Multi-Criteria Decision Analysis (MCDA) offers exactly this framework. Being a set of approaches aimed at assisting in making decisions in the situation that presuppose the presence of multiple and possibly conflicting criteria, MCDA allows organizations to consider alternatives in a systematic and openly fashioned way. The widely used methods in the selection of suppliers in different industries include Analytic Hierarchy Process (AHP), Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) and various hybrid versions (Cebi and Bayraktar, 2003; Kannan et al., 2013; Stevic et al., 2020). Nevertheless, the empirical studies in the manufacturing industry, especially in the case of textile and garments firms in Bangladesh, are limited, and it is a great gap in literature.

This thesis fills that gap by using MCDA to the process of supplier selection of Monno Fabrics Ltd. which is a leading company producing textiles in Bangladesh. As a company, having a complex and geographically spread base of suppliers, Monno Fabrics Ltd. continuously struggles to ensure that procurement efficiency, consistency of supplier performance and transparency of procurement decisions are observed. The research is expected to come up and prove a supplier evaluation model based on MCDA to fit the environment of the company, making its contribution both to the academic literature on the topic of supply chain management as well as to the practical development of the procurement process in the organization.

### **1.1 Background and Motivation**

Monno Fabrics Ltd. is a vertically integrated textile manufacturing firm based in Bangladesh, and it produces a mixed variety of woven as well as knitted fabrics to its domestic and export markets. Being one of the most competitive industries in which Bangladesh is one of the largest exporters in the world, Monno Fabrics Ltd. is highly reliant on a well-working and inexpensive supply chain. The sourcing of raw materials, such as yarn, dyes, chemicals and auxiliary materials, comes with contact to a wide diversity of suppliers both local and foreign. Due to the volume, diversity and strategic nature of such procurement activities, the quality of supplier selection decisions directly impact the operational performance and financial sustainability of the company.

The force behind this study can be traced back to a real life organizational problem that is realized in Monno Fabrics Ltd. After initial consultation with the senior management including Mr Habibur Rahman ACMA, Chief Financial Officer of the company, it was realized that the existing supplier assessment system does not have a formalized, multi-criteria system. The selection of suppliers is sometimes done based upon the relationship established, on the competitiveness of the price, and an informal evaluation of quality in a manner that does not entail a systematic process to evaluate all the factors involved. This lack of the procurement decisions creates subjectivity and inconsistency in the procurement decisions, it raises the risk of supplier-related disruption and it does

not allow the organization to benchmark and make continuous improvement on its supplier base.

Theoretically, one of the most widespread issues of supply chain management has been supplier selection. Early suppliers research by Dickson (1966) found 23 criteria applicable to supplier evaluation and the decades that have followed have witnessed the development and improvement of many quantitative and qualitative methods. Among them, MCDA-based techniques have received some of the most popularity because of their capacity to address complex trade-offs, deal with both subjective and objective data as well as generate transparent and auditable results (Ho et al., 2010; Govindan et al., 2015). The use of these techniques with reference to Bangladeshi manufacturing firms, however, is not properly studied, and this study is timely and relevant.

The scholarly significance of the study is also supported by the increased attention to the resilience and sustainability of supply chain. Following global disruptions of supply chains in the recent past (such as the one caused by the COVID-19 pandemic), companies across all industries have identified the strategic necessity of diversifying and carefully assessing their supplier base. Supplier selection schemes based on the MCDA concept do not only improve the operational efficiency of the routine procurement activity but also help with the supply chain risk aversion by ensuring that a wider range of performance dimensions is systematically evaluated (Ivanov et al., 2019).

## **1.2 Research Problem**

The main research issue which the thesis presents is the lack of coherent, multi criteria supplier evaluation system in Monno Fabrics Ltd. The existing procurement decision-making process of the company lacks a systematic integration of all pertinent dimensions of supplier performance, as well as it does not offer a clear mechanism of weighting and comparison of such dimensions. Consequently, procurement choices can be suboptimal and the basis of the selection choice of suppliers can hardly be documented, communicated or replicated.

This is not the only issue with Monno Fabrics Ltd. There is an even greater problem in the Bangladeshi textile industry where the development of high rates of growth and the

aggressive competition in the world market has put significant pressure on procurement functions without proportional development of decision support tools and methodologies. It is repeatedly mentioned in the literature that implementing formalized techniques of MCDA in the procurement process can produce the tangible benefits in terms of supplier quality, cost efficiency, and consistency of decisions (Cebi & Bayraktar, 2003; Kannan et al., 2013). Nevertheless, the change that should be made between the informal and formalized procurement decision making must be carried out attentively to identification of the context-specific evaluation criteria, active involvement of the relevant stakeholders in the weighting process, and development of the tools that can be practically implemented within the current organization process.

The given research thus seeks to answer the following two-fold challenge: first, to create an empirically-based MCDA model of supplier selection that will reflect the peculiarities of Monno Fabrics Ltd. procurement, and second, to assess how the model in question can fit into the procurement decision-making process and contribute to enhanced transparency, consistency, and management of the supplier relationship of the company.

### **1.3 Research Questions and Objectives**

To answer this research problem as stated above, this study will be guided by five inter-related research questions. These queries easily advance in a logical sequence by identifying criteria all the way to the implementation of the model, prioritization, sensitivity analysis, and, lastly, integration into the organization:

1. RQ1: Which are the main criteria to be taken into consideration when suppliers are selected in Monno Fabrics Ltd. at the textile manufacturing industry?
2. RQ2: What is the way to use Multi-Criteria Decision Analysis to systematically consider and rank suppliers with regard to the identified criteria?
3. RQ3: Which suppliers will be the best option to Monno Fabrics Ltd. once the MCDA is applied to the suppliers?
4. RQ4: How the supplier selection results depend on the weighting of the evaluation criteria?

5. RQ5: What organizational conditions, process-related requirements are needed to implement an MCDA-based approach into the procurement decision-making process at Monno Fabrics Ltd?

To answer these research questions, the research is designed based on five objectives that are aligned with the questions:

1. To draw up and confirm the main supplier assessment requirements in the procurement situation of Monno Fabrics Ltd., relying on the academic literature as well as the professional experience within the company.
2. To create and use an MCDA model, including AHP and TOPSIS methods, to assess and rank a group of current or potential suppliers to the reflective criteria.
3. To identify the best suppliers to be used by Monno Fabrics Ltd. using the results of the MCDA evaluation.
4. To perform a sensitivity analysis in order to estimate the strength of the supplier rankings with different weights on criteria.
5. To develop evidence-based suggestions on how to incorporate the MCDA framework in the current procurement procedures of Monno Fabrics Ltd.

#### **1.4 Scope and Limitations**

This study is specifically aimed at a narrower scope in order to achieve methodological rigour and practical feasibility. Regarding the scope of the organization, the research targets at the organizational procurement operations of the Monno Fabrics Ltd. and the supplier selection decisions with regards to the core manufacturing inputs of the company such as raw materials, chemicals, and other important auxiliary supplies. The research does not go further within the context of other companies of any affiliated group or downstream supply chain operations like distribution and logistics.

Geographically, the scope of the study will include the suppliers who are located in Bangladesh and the major international suppliers where Monno Fabrics Ltd. has active procurement relations. The suppliers to be assessed will be chosen after consultation with the senior procurement and finance management of the company where the sample will be chosen based on the actual procurement environment of the organization.

It must be noted that there are a number of limitations. First, the study utilizes heavily on the expert judgment on weighting of the criteria, which brings in the aspect of subjectivity. Despite the fact that the AHP methodology offers a systematic way of obtaining and combining expert preferences, the findings depend on the idea and knowledge of the individuals, with whom one communicates. Second, information availability can limit the scope of quantitative supplier performance variables to be introduced in the model. The accuracy of the quantitative elements of the assessment will depend on the quality and fulfilment of the procurement records at Monno Fabrics Ltd. Third, the results of this research can be mostly generalized to the particular organizational and sectoral setting under research; one should be careful with the generalization to other companies or industries.

### **1.5 Structure of the Thesis**

This thesis is divided into 5 main chapters which address each a different aspect of the research. After this introduction chapter, Chapter 2 will introduce a review of all the related literature in the field of supplier selection, supply chain management, and Multi-Criteria Decision Analysis. The review provides the theoretical backgrounds of the research, reveals the main criteria that are typically applied in the process of supplier evaluation and puts the current research into the context of the existing literature.

In chapter 3, the methodology adopted in this study is explained. It describes the research design, the choice and justification of MCDA methods (that is, AHP and TOPSIS), data collection process, and the approach to analysis which is sensitivity analysis. Some ethical considerations which were considered and the measures taken to interpret the validity and reliability of the research are also discussed in the chapter.

In Chapter 4, the results of the research are revealed. It entails the findings of the criteria identification and weighting exercise, the findings of the supplier evaluation process and the sensitivity analysis along with an interpretation of findings in view of the research questions. Chapter 5 concludes the thesis by summarizing the main findings, explaining their theoretical and practical consequences, and providing suggestions of how to apply the MCDA framework to the implementation in the Monno Fabrics Ltd. The chapter also contemplates the drawbacks of the study and gives suggestions of future research directions.

## **2 Literature Review**

This chapter will provide a critical review and systematic literature review of scholarly works pertaining to the current research. The review is organized with five thematic areas that are directly related to the research questions and objectives developed in Chapter 1. The chapter starts by looking at the bigger picture of the supply chain management and the strategic position of procurement in the same. It then examines scholarly debate on supplier selection such as development of evaluation criteria. The chapter then discusses Multi-Criteria Decision Analysis (MCDA) as a methodological tradition, specifically, the Technique of Analytic Hierarchy Process (AHP), as well as the Technique of Order of Preference by Similarity to Ideal Solution (TOPSIS). The discussion then covers hybrid and integrated MCDA approaches, and it is concluded by the discussion of their use in a textile and manufacturing context. The chapter ends with the identification of those theoretical and empirical gaps, which this thesis aims to fill.

### **2.1 Supply Chain Management and the Strategic Role of Procurement**

The principle of supply chain management (SCM) may be loosely understood as the coordination, as well as integration, of all activities involving the movement of materials, information, and finances between the raw material suppliers, the manufactures, and the distributors to the final consumer (Mentzer et al., 2001). SCM has transformed in the last 30 years, becoming more of a strategic field than a more operational-related issue that revolves around inventory management and efficient logistics to include supplier relationship management, mitigation of supply chain risks, sustainability, and competitive differentiation (Christopher, 2016). The design and the performance of the supply chain are universally known to be the main factor of firm-level competitiveness in the knowledge-intensive as well as the manufacturing-intensive industry (Chopra and Meindl, 2016).

The procurement holds a central strategic position within the framework of the wider SCM. The choices of procurement define the quality of inputs into the production system,

the cost of these inputs, and the reliability thereof, and thus directly affect the results of the manufacturing process and customer satisfaction (van Weele, 2018). The shift of procurement as a transactional activity to a strategic capability is also widely covered in the literature (Monczka et al., 2015). Strategic procurement involves the development of suppliers over the long term, the management of the supplier base as a portfolio, the evaluation of risks and how the procurement activities are aligned to the overall corporate goals.

The strategic value of procurement is heightened in the global textile and garments industry since the industry is typified by the fact that most of its inputs are supplied by outside suppliers. As a major exporter of garments in the world, Bangladesh is a rather relevant context to study procurement practices. The high rate of growth, introduction to international standards of quality and exposure to supply chain risks such as fluctuations in raw material prices and changes in geopolitics, allow making the optimisation of the selection of suppliers a question of operational need and competitive strategy (Adhikari & Weeratunge, 2007; Anner, 2019). Monno Fabrics Ltd. companies are not an exception because they are forced to work in an environment that predetermines the presence of a challenging environment where procurement decisions can influence the ability to compete in export and financial sustainability directly.

## **2.2 Supplier Selection: Concept, Significance, and Evolution**

Supplier selection refers to the act whereby a purchasing organisation reviews and selects the suppliers among the available options on a list of predetermined criterion. The academic research on supplier selection has a rich and fruitful history, though most would agree that the major breakthrough occurred with the publication of the seminal survey of purchasing managers by Dickson (1966), who came up with 23 criteria that might be used in supplier selection. Out of these, the most important ones were always quality, performance in delivering, and the price. The paper by Dickson has defined that the selection of suppliers is, in itself, a multi-criteria issue, since no one supplier would be the best at all dimensions at the same time.

Several decades after the contribution of Dickson, the literature on supplier selection has grown greatly in scope and in the level of methodological adherence. Weber et al. (1991) reviewed a total of 74 articles published between 1966 and 1991 and thus established that the criteria based on price, quality and delivery still prevailed in practice but did find an increased application of quantitative decision models. The further development of MCDA-based methods was reported by Ho et al. (2010) and Govindan et al. (2015) in the 2000s and 2010s, respectively, as part of the general shift to evidence-based and transparent procurement decisions.

A more recent stream in the literature has applied the supplier selection framework to include a sustainability aspect, such as environmental performance, social responsibility and supply chain transparency (Seuring and Mueller, 2008; Zimmer et al., 2016). The identification of green suppliers has gained a specific interest of scholars as a reaction to increasing regulatory and consumer demands on companies to act as environmental stewards across their supply chains. Sustainability matters have become more topical to Bangladeshi manufacturers in the view of the increased attention to the environmental and labour practices adopted in the realm of the sector by global consumers and regulators (Anner, 2019).

Supplier selection is more than cost-saving and quality guaranteeing. Empirical studies prove that the quality of decisions in supplier selection is positively related to the supply chain resilience because companies with properly assessed and diversified supplier base are better placed to absorb and recover disruptions (Ivanov et al., 2019). Moreover, the good suppliers are also selected to facilitate the long term partnerships of supplier development whereby the buying organisations and the supplier collaborate to invest in process refinement and capacity building (Dyer and Singh, 1998). These dimensions of strategy highlight the need to embrace stringent, systematic methods of supplier assessment.

### **2.3 Supplier Evaluation Criteria**

Determining suitable evaluation criteria is also a pre-requisite in the process of supplier selection. The criteria employed should indicate the buying situation, strategic interests

of the participating buying organisation and the type of goods or services he or she is buying. The scholarly sources provide a wealth of advice in terms of choosing the criteria, as it is based not only on the theoretical foundations but also on the experience of the industry.

### **2.3.1 Classical Criteria Frameworks**

It is based on the work of Dickson (1966) that the criteria that are most frequently mentioned in the supplier selection literature can be grouped into several broad categories. Quality also includes the conformance quality of the materials supplied and the quality management systems and certification used by the supplier like the ISO 9001. Delivery performance entails on- time delivery rate, lead time and responsiveness to change of order volume or specification. Not only does price and total cost of ownership consider the quoted unit prices, but also the cost of transaction, inspection cost, and supplier related failures cost. Financial and business stability is used as a parameter of evaluating the capacity of the supplier to maintain business and fulfil agreements in the long run (Weber et al., 1991; Deng et al., 2014).

Other criteria that have become more prominent in more recent literature are technical enablement and innovativeness capacity, after sales service and responsiveness, proximity and logistics infrastructure, and relationship history and trust. These criteria differ significantly in relative significance depending on industry and procurement situations. Fabric quality consistency, accuracy in dyeing and finishing, and lead-time reliability are usually put relatively to a greater weight in the textile industry than in other production settings (Kannan et al., 2013).

### **2.3.2 Sustainability and Risk Criteria**

The transformation of the supplier assessment structures to the dimension of sustainability and risk is a reflection of the shift in the expectation laid on the global supply chains. Firms aiming to attain green supply chain goals have implemented environmental stand-

ards, including carbon footprint, waste management systems, and adherence to environmental regulations in their supplier assessment systems (Seuring and Mueller, 2008; Govindan et al., 2015). Social standards, such as labour norms, health and safety measures, adherence to fair trade principles, among others, are especially relevant in the garments industry of Bangladesh where global consumers often force their suppliers to adhere to a set of codes of conduct (Anner, 2019).

Supplier concentration risk, which is part of the supply chain risk criteria, has recently obtained increasing scientific interest as a result of the disruptions experienced during the COVID-19 pandemic and due to other global supply chain shocks (Ivanov et al., 2019; Dolgui et al., 2020). Risk criteria integration into MCDA-based supplier selection models allows organisations to make performance-trade-off procurement decisions involving risk minimisation, whose trade-off is increasingly being accepted as a core strategic requirement.

## **2.4 Multi-Criteria Decision Analysis: An Overview**

Multi-Criteria Decision Analysis (MCDA) or Multi-Criteria Decision-Making (MCDM) is a term that includes a group of approaches which are used to assist in decision-making in scenarios where multiple and even conflicting objectives or criteria are involved (Belton and Stewart, 2002). This is the main problem that MCDA is resolving; a real-world decision can hardly be represented by a single optimal solution; instead, it implies the trade-off between competing dimensions of performance. MCDA offers systematized methods of determining, rating, and combining these criteria in a manner that is clear, auditable, and based on the preferred metrics of the stakeholders.

The literature of MCDA highlights the existence of a number of methodological traditions. The utility-maximisation theory based on decision theory is the multi-attribute utility theory (MAUT) and its derivatives (Keeney and Raiffa, 1976). The outranking approaches, such as ELECTRE and PROMETHEE, compare the options in pairs and find out some partial or full preference ranking without a complete utility aggregation (Brans and Vincke,

1985; Roy, 1991). The compromise-ranking based approach, such as VIKOR, finds the solutions nearest to an optimal point, and group utility is maximized (Opricovic and Tzeng, 2004). One of the most common approaches used in applied research is the AHP, and TOPSIS approaches, which are best applicable in the problems of selecting suppliers with a limited amount of options and a set of criteria with an organized list of measurable characteristics.

In a systematic review of MCDM applications in supplier selection, published in 2000-2008, Ho et al. (2010) discovered that the most popular approach to using MCDM was AHP, either alone or in conjunction with other models, then hybrid models of AHP with linear programming, TOPSIS, data envelopment analysis (DEA). This supremacy is indicative of the intuitiveness of the method, its capacity to deal with both qualitative and quantitative criteria, and its appropriateness in attracting organisational experts in the process of weighting. More current review articles (Govindan et al., 2015; Stevens et al., 2020) confirm the fact that AHP and TOPSIS are still considered dominant, but they have an emerging tendency to consider fuzzy extensions of these techniques to the problem of imprecision inherent in the expertise judgement.

## **2.5 Analytic Hierarchy Process (AHP)**

Saaty (1980) has developed the Analytic Hierarchy Process (AHP) which has been among the most commonly used MCDA processes in both academic literature and practice within the management field. AHP models a decision problem as a hierarchy having three levels: the top has an overall goal, the intermediate levels have a set of criteria and sub-criteria, and the bottom has the decision alternatives. The approach will follow a sequence of two-way comparisons, where decision-makers will indicate the relative importance of each criterion compared to the other in a 1-9 ratio scale. Such comparisons are then summarized into reciprocal matrices, and priority vectors (weights) are calculated by computing an eigenvalue.

An unusual attribute of AHP is its consistency ratio (CR) process, and this will offer a numerical evaluation of the logical consistency of the pair-wise comparison judgments. A consistency ratio of less than 0.10 is considered to be acceptable which means that

the judgments are relatively consistent to provide reliable weight of priorities (Saaty, 1980; Vaidya and Kumar, 2006). The above inbuilt consistency check is one of the reasons why AHP is especially appreciated in the organisational decision-making situation where a more than one stakeholder influences the weighting process and a certain level of inconsistency of judgements cannot be avoided.

The use of AHP in the selection of suppliers is not a new concept and is well-documented. Cebi and Bayraktar (2003) established the relevance of AHP to manufacturing procurement, and revealed that structured pair-wise comparison can be successfully used to elicit and aggregate managerial preferences on criteria of supplier evaluation. Deng et al. (2014) used AHP to the selection of suppliers in the field of electronics and they found that quality and reliability in delivery were always given the highest proportionate weight when calculated by experienced procurement managers. Kannan et al. (2013) used AHP in textile industry with grey relational analysis to assess the quality of green suppliers and found that the environmental management and the control of pollution became improved weighted factors against the traditional performance dimensions.

Although AHP has strengths, it has received a number of criticisms. The technique uses  $n(n-1)/2$  pair-wise comparisons on  $n$  criteria which may be cumbersome with large sets of criteria. Furthermore, AHP is vulnerable to the problem of rank reversal, the occurrence of which causes the changes in the relative ranking of the remaining alternatives after the introduction or removal of an alternative. This shortcoming has encouraged the application of AHP as one of criterion weighting and not complete alternative ranking (Saaty and Vargas, 2012). Criterion weighting, where weighting is done with AHP is hence, used in this study and the decision of the final supplier is left to TOPSIS.

## **2.6 TOPSIS: Technique for Order of Preference by Similarity to Ideal Solution**

Hwang and Yoon (1981) introduced TOPSIS, as a means of determining the alternative that is both nearest to a positive ideal solution (PIS) and farthest to a negative ideal solution (NIS). The PIS is a hypothetical alternative which costs optimally on all criterion whereas the NIS represents worst performance values. The real alternatives are ranked

on the basis of their relative closeness coefficients, a non-negative scalar value ranging from zero to one, which is the proportional distance of the real alternative to the NIS in comparison with the overall distance between the PIS and the NIS.

TOPSIS has a computational process that follows six steps: construction of the normalised decision matrix; construction of the weighted normalised decision matrix with criterion weights calculated using AHP; identification of the PIS and NIS vectors; calculation of the Euclidean distance of each alternative to the PIS and NIS; calculation of the relative closeness coefficient; and the ranking of the alternatives in a descending sequence of the difference in proximity (Hwang and Yoon, 1981; Behzadian et al., 2012). This process is computationally transparent and gives results which can be immediately interpreted into the closeness to the ideal supplier profile.

A number of practical benefits associated with TOPSIS makes it very appropriate in selection of suppliers. The algorithm is computationally simple and does not require the exponential increase in comparisons that is necessary with AHP. It works with both normalised and quantitative data, and can be interpreted about an intuitive distance-from-ideal measure. In a thorough review of TOPSIS applications, Behzadian et al. (2012) found supplier selection one of the most frequently used areas of application, which included manufacturing, logistics, construction, and services. This hybrid has turned out to be a popular combination of AHP to weight and TOPSIS to rank, thus (Ho et al., 2010; Stevens et al., 2020).

## **2.7 Hybrid MCDA Approaches and Sensitivity Analysis**

Combinations of various MCDA techniques into hybrid models is an important development in the literature of suppliers selection, as efforts have been undertaken to acknowledge that each of the methods possesses specific flaws and constraints that have been addressed through other approaches. The hybrid between AHP and TOPSIS takes advantage of the structured elicitation of expert preference in AHP with regard to criterion weighting and efficiently manages the alternative ranking in TOPSIS, hence, merging the strong sides of both approaches while reducing the weak ones (Deng et al., 2014; Stevens et al., 2020).

Other hybrid methods that have been popularized in literature are the integration of the fuzzy set theory with AHP or TOPSIS. The subjectiveness and imprecision of the expert judgments are solved in Fuzzy AHP and Fuzzy TOPSIS, which reflect the linguistic variables in triangular or trapezoidal fuzzy numbers (Kahraman et al., 2003; Chen, 2000). This is more applicable to fuzzy extensions when the decision-making environment is said to be characterised by ambiguity and the accuracy of judgements that are made by pairwise comparison cannot be assured. Despite the fact that this paper deals with the sharp AHP-TOPSIS model, the effects of uncertainty in the criterion weight are discussed using the sensitivity analysis.

The sensitivity analysis is an important element of an MCDA-based decision study. It looks at the effect of the variation in the input parameters i.e. the criterion weights on ranking the alternatives. Sensitivity analysis can determine how robust or fragile the selection results are and the criteria that the result of supplier rankings is most subject to change by systematically manipulating the weights of the individual criteria and noting the degree of the resulting changes in the supplier rankings. Practically, such information is of great importance to the decision-makers because it will help to focus on the criteria that should be carefully and consistently evaluated in practice (Govindan et al., 2015; Triantaphyllou and Sanchez, 1997).

## **2.8 MCDA Applications in Textile and Manufacturing Procurement**

An increasing amount of empirical evidence has been reported of the use of MCDA techniques in the selection of suppliers within the textile, garments and expanded manufacturing environments. These studies offer valuable points of reference to the current study, both regarding which criteria can be considered the most crucial and what methodological options prove to be the most productive.

Kannan et al. (2013) used a hybrid model of AHP-grey relational analysis to select green suppliers in a textile manufacturing company and found the environmental management, green product design, and pollution control to be of the highest weights in addition to the traditional quality and delivery criteria. In their research, they have highlighted that sustainability requirements are not just some extra-curricular activities that can be

added to the traditional systems but become part and parcel of supplier appraisal in the export-based manufacturing. In an extensive literature review of 181 articles that focused on sustainable supplier selection, Govindan et al. (2015) discovered that around 40 percent of the literature dealt with manufacturing industries with textile and apparel industry being the most common sectors examined in the studies.

The hybrid framework of the supplier selection in a manufacturing situation as suggested by Stevens et al. (2020) proved the usefulness of integrating both the stakeholder-oriented weighting and compensatory ranking approaches. Their results supported the significance of delivery performance and product quality as overriding parameters and the evolving significance of supplier flexibility and responsiveness in dynamic production settings. Cebi and Bayraktar (2003) in their AHP-based analysis of a Turkish manufacturing company made similar conclusions as they found that quality management systems and reliability of their deliveries were regularly regarded as a priority by procurement managers in that company.

To be more exact, the literature on supplier selection is limited in the scope and diversity of methods when it comes to Bangladesh. However, the literature on the topic has been dominated by the research on buyer-supplier relationship and compliance management within the ready-made garments (RMG) industry (Anner, 2019), and formal MCDA-based assessment frameworks are hardly covered. This is a major loophole because the complexity of operations and the intensity of purchasing by the manufacturing companies in Bangladesh would make them automatic targets on which structured decision-support tools can be implemented. This gap is directly covered in the current study which deploys the AHP-TOPSIS framework on the procurement environment of Monno Fabrics Ltd.

## **2.9 Theoretical Framework and Research Gap**

This thesis is based on a decision science viewpoint on the selection of suppliers based on the literature reviewed in the sections above. The theoretical framework is a combination of three bodies of knowledge that are interrelated: first, strategic procurement and supply chain management literature identifies the organisational setting and strate-

gic justification of the criteria to be deployed in the MCDA model, second, supplier evaluation criteria literature, which gives the empirical foundation of the criteria to be deployed in the MCDA model, and third, MCDA methodology literature, which informs the design and application of the AHP-TOPSIS framework.

This study is based on a conceptual model that suggests that the performance of supplier selection is based on three factors that are interrelated, which are the comprehensiveness and context-relevance of the selection criteria, the accuracy and consistency of the weight of selection criteria as a result of expert judgement, and the methodological rigour of the selection procedure. The hybrid method of AHP-TOPSIS framework is being proposed as the methodological means of implementing this conceptual model in particular, Monno Fabrics Ltd. context.

The literature analysis shows that there are three distinct gaps that are addressed by this thesis. On the one hand, the empirical research of MCDA-based supplier selection is scarce within the context of the Bangladeshi manufacturing industry, and the literature of the global literature has a geographical and industry gap. Second, the literature in the textile industry has seldom incorporated procurement-oriented financial objectives, including payment terms, financial stability, and cost transparency, and operational and sustainability objectives within a single MCDA model. Third, the literature has given little focus to the organisational requirements needed to actualise practical application of MCDA frameworks in procurement contexts especially in organisations that are changing their informal to formalised decision-making. These three gaps make this thesis valuable to the scholarly literature on supply chain management and MCDA as well as to the current knowledge base that procurement specialists can use in the textile and manufacturing industries.

Table 1 gives an overview of the major researches that were examined in this chapter and summarizes their methodologies, contexts, and main findings. This overview shows the methodological course of the discipline and places the current research into the context of the existing literature.

**Table 1. Summary of key studies on supplier selection and MCDA (author's compilation).**

Author(s) & Year	Methodology	Industry / Context	Key Finding(s)
Dickson (1966)	Purchasing manager survey	General manufacturing	Identified 23 evaluation criteria; quality, delivery, and price ranked highest.
Weber et al. (1991)	Literature review (74 studies)	Multi-industry	Price, quality, and delivery dominate; growing adoption of quantitative models.
Saaty (1980)	AHP development	Theoretical	Pairwise comparison framework with consistency ratio for reliable criteria weighting.
Hwang & Yoon (1981)	TOPSIS development	Theoretical	Distance-from-ideal ranking method; applicable to MCDM problems with multiple criteria.
Cebi & Bayraktar (2003)	AHP	Turkish manufacturing	Quality management systems and delivery reliability are top-weighted procurement criteria.
Ho et al. (2010)	Systematic review	Multi-industry	AHP is the most widely used method; hybrid approaches are increasingly prevalent.

Kannan et al. (2013)	AHP + Grey Relational Analysis	Textile manufacturing	Environmental criteria increasingly weighted alongside quality and delivery dimensions.
Deng et al. (2014)	AHP	Electronics manufacturing	Quality and delivery dominate; financial stability is a significant secondary criterion.
Govindan et al. (2015)	Literature review (181 studies)	Multi-industry incl. textile	Sustainability criteria integral to evaluation; MCDA is the dominant methodology.
Ivanov et al. (2019)	Conceptual/empirical review	Supply chain resilience	Rigorous supplier selection and diversification enhance supply chain resilience.
Stevens et al. (2020)	Hybrid MCDA model	Manufacturing	Delivery performance and flexibility are critical; hybrid methods improve ranking accuracy.

As illustrated in Table 1, the field has evolved from descriptive criterion-listing studies in the 1960s and 1970s toward increasingly sophisticated quantitative and hybrid methodological approaches. The present study builds on this trajectory by applying an AHP-TOPSIS framework in a context, specifically Bangladeshi textile manufacturing, that is both practically significant and underrepresented in the extant literature. The following chapter describes the methodological design adopted to operationalise this framework in the specific organisational setting of Monno Fabrics Ltd.

## **03 Methodology**

### **3.1 Introduction**

This chapter shows the methodological approach that will be used in this thesis to answer the five research questions that have been formulated in Chapter 1. The chapter presents the philosophical stance behind the research design, rationale behind adopting one of the case study-based research strategies, and details the data collection process, how the AHP-TOPSIS framework is operationalised, how the sensitivity analysis is analysed, and the ethical and quality assurance issues guiding the study. The epistemology and ontology assumptions used to guide the methodology are those of a decision-science study, in which the ultimate goal is to develop and test an evidence-based, replicable, quantitative model of supplier selection.

The chapter is organized in accordance with the framework of the research onion of Saunders et al. (2019), beginning with the layers of philosophical assumption that are most distant and then moving to the layers of data collection and the data analysis method most closely related to the study topic. Each of the methodological options is justified referring to the existing academic literature as well as the needs of the concrete research scenario in Monno Fabrics Ltd.

### **3.2 Research Philosophy**

This study has a philosophical basis of pragmatism. Pragmatism is an epistemological approach that puts greater emphasis on the practical usefulness of knowledge and does not exclude the fact that both objective and subjective data can be used to provide valid and reliable results so long as they serve the purpose of the research (Creswell and Creswell, 2018; Saunders et al., 2019). The best philosophical standpoint to this thesis is pragmatism, since the research problem is basically applied in nature: the goal is to come out with a practical MCDA model to Monno Fabrics Ltd., not to come up with theoretically generalisable propositions.

The positivist approach would limit the research to objective quantifiable procurement performance data and would not consider the justifiable presence of expert judgment in building criteria weights, which is an inherent aspect of the AHP approach. In contrast, a pure interpretivist position would not help in exploiting the quantitative form and analytical rigour with which the MCDA model is endowed with decision-support significance. Pragmatism attempts to address this tension in that both objective records of performance as well as structured expert elicitation can be drawn on by the researcher, and all these may be put in a consistent analytical framework (Morgan, 2007).

The criticism realism is ontologically consistent with the position taken by the study. The Monno Fabrics Ltd. procurement environment is approached as a real-life system the performance characteristics of suppliers, the resultant procurement are observable properties which can be partially captured by the structured measurement and the expert judgment but an understanding that such measurement must always be mediated by the perceptions and knowledge of the informants (Bhaskar, 1978; Archer et al., 1998).

### **3.3 Research Approach**

The type of research taken is deductive. In deductive methodology the researcher starts with prior theory, which he or she applies to empirical evidence in order to test or operationalise theoretical propositions (Bryman, 2016). The thesis is based on the already existing theoretical foundations of MCDA namely the AHP model by Saaty (1980) and the TOPSIS model by Hwang and Yoon (1981) and then uses these models in the particular procurement context of the Monno Fabrics Ltd.

The criteria used in the MCDA model are based on the literature of supplier selection in Chapter 2 and the analytical processes are conducted in accordance with the formalisations in the seminal methodological literature. This is where deductive reasoning can be used as the conceptual model is not being developed in this case but is being implemented and tested in a new organisational and geographical environment. This inductive reasoning stems out of the generic theoretical context (AHP-TOPSIS in the context of selecting suppliers in multi-criteria) towards the specific situation (Monno Fabrics

Ltd., Bangladeshi textile manufacturing) to the final results of the theory (empirically justified supplier ranking and integration advice). It should be noted that originally another company had been selected as the case organisation for this research; however, as it became impossible to arrange the necessary access and cooperation, the study was redirected to Monno Fabrics Ltd. as an alternative case. This change did not affect the methodological integrity of the research, as Monno Fabrics Ltd. constitutes an equally appropriate and theoretically relevant case for studying MCDA-based supplier selection in the Bangladeshi textile manufacturing context.

### **3.4 Research Strategy**

The study design used is one embedded case study. Case study strategy is suitable when the questions of research are preoccupied with how and why questions, when the researcher lacks control over the events, and when the researcher is interested in a real-life phenomenon in its context (Yin, 2018). These five research questions of this thesis such as the criteria identification, application of the model, ranking suppliers, sensitivity testing, and organisational integration are exactly of this nature. They deal with a restricted and particular decision-making problem in an outlined organisational context.

Monno Fabrics Ltd. is chosen as the case organisation due to its theoretical and practical value as a broader research problem: a manufacturing company that has to work in the environment where MCDA-based supplier selection is a must and is not provided. The case is elaborated as embedded whereby the unit of analysis is not the whole organisation, but the particular process that the procurement entails and the decisions related to supplier selection that are made within it (Yin, 2018).

Although the single case design precludes statistical generalisation, it allows analytical generalisation the application of findings to theory and similar procurement situations (Yin, 2018; Stake, 1995). The orientation of decision science used in this measure focuses on the definition of a verified, repeatable model instead of statistical inference of the population level. The use of case study methodology is thus aligned with applied and problem solving nature of the study.

### 3.5 Research Design Overview

Table 3.1 provides a summary of the research design adopted in this study, mapping the key dimensions of the methodological framework to the positions and choices made.

**Table 3.1. Research design summary.**

Research Dimension	Position Adopted
Research Philosophy	Pragmatism — combining positivist quantitative analysis with interpretivist expert elicitation to address a real organisational problem
Research Approach	Deductive — theory-driven application of established MCDA methods (AHP and TOPSIS) to an empirical procurement context
Research Strategy	Single embedded case study — Monno Fabrics Ltd., Bangladesh
Methodological Choice	Mono-method quantitative — primary data from structured expert elicitation; secondary data from procurement records
Time Horizon	Cross-sectional — data collected at a single point in time during the fieldwork period
Data Collection	Structured pairwise comparison questionnaires (AHP); procurement performance records (TOPSIS input)
Data Analysis	AHP eigenvector method (criteria weighting) → TOPSIS (supplier ranking) → Sensitivity analysis (robustness testing)

### 3.6 Data Collection

The data gathering plan of this research consists of two complementary streams, first of all data collected in the form of primary data primary data: is structured expert

elicitation of data to weight the AHP criteria and secondly, derived data in the form of primary data: is secondary data through the procurement records of Monno Fabrics Ltd. to score the supplier performance as per TOPSIS.

### **3.6.1 Primary Data: Expert Elicitation for AHP Criteria Weighting**

The AHP part of the analysis involves gathering of pairwise comparison judgments of informed informants at Monno Fabrics Ltd. Expert judgment elicitation is an established and methodologically suitable tool in ascertaining criteria weights in MCDA-based supplier selection, especially in an organisational set up where historical performance data might be unavailable to all pertinent evaluation dimensions (Saaty, 1980; Vaidya and Kumar, 2006).

Purposive sampling technique is taken to choose the expert panel. The purposive sampling is applicable in decision-science and qualitative studies when the aim is to make sure that the subjects are the best suited to the research's goal in terms of offering the necessary knowledge and experience (Patton, 2002). The inclusion criteria to be on the expert panel shall include: (i) current or recent managerial position with direct responsibility of procurement, supply chain, finance or quality assurance at Monno Fabrics Ltd.; and (ii) at least three years experience in the functional area in which they will operate. According to these requirements, the expert panel should include three to five senior staff, which will include the representatives of the Procurement department, Finance department and Quality Assurance department.

The process of data collection is performed via structured pairwise comparison questionnaire, which will be given to the individual panel members. Each combination of the possible evaluation criteria is described in the questionnaire and the respondent is requested to rate on Saaty scale (1980) of nine on the comparison scale the relative importance of one criterion over the other (see Table 3.3 below). A geometric mean method is used to combine individual responses, and it has been discovered in the literature to be the best technique to combine individual pair variants judgment in the form of a group matrix (Dyer and Forman, 1992; Saaty and Vargas, 2012).

Before conduction of questionnaire, the researcher holds a briefing meeting with all the experts to clarify the purpose of the study, the format of the pair-wise comparison process, and the interpretation of the scale scores. This briefing is performed either physically or via video conference basing on the accessibility of participants. The questionnaire will be conducted either in written or electronic format, and the participants will have a chance to reword their answers after explaining the results of the consistency ratio.

The semi-structured expert interviews are also administered to facilitate the quantitative elicitation. These interviews will discuss a context of operation of procurement at Monno Fabrics Ltd., informal criteria that is used in the selection of suppliers presently, and the organisational needs to incorporate an ordered MCDA strategy. The interview data used only inform the answers to RQ1 and RQ5 and are analysed through the thematic analysis to identify recurrent themes applicable to the criteria selection and organisational integration.

### **3.6.2 Secondary Data: Procurement Records for TOPSIS Input**

The TOPSIS element of the analysis needs the objective or semi-objective data regarding the work of candidate suppliers in terms of the identified evaluation criteria. These information are obtained in the form of the vendor delivery performance records, quality inspection records, price comparison records, and supplier financial records which are maintained in the procurement and financial departments of the company.

The researcher has acquired the access to such records by agreement with the top management of Monno Fabrics Ltd., chief financial officer and Assistant General Manager of Procurement. The access protocol of the data is regulated by the confidentiality agreement, according to which raw data of the suppliers is anonymised in the presentation of findings, which is necessary to avoid the commercial secrets exposure. In all the tables, figures and discussions given in the thesis, the name of suppliers is substituted with alpha numeric code (e.g. Supplier A, Supplier B).

In situations where quantitative procurement information is either unavailable or too coarse to meet one or more criterion, especially those of qualitative nature like responsiveness, relationship quality and environmental compliance, the panel is elicited to provide expert-rated ratings on a structured 1-to-10 performance rating scale. This mix of objective records and systematic expert ratings is in line with the existing practice of MCDA-based evaluation of suppliers (Ho et al., 2010; Stevens et al., 2020).

### **3.7 Criteria Selection and Operationalisation**

One of the most important steps that make up a supplier selection study that is based on MCDA is the identification and operationalisation of evaluation criteria. As outlined in Chapter 2, the literature on supplier selection is highly enriched with criteria frameworks, starting with the most iconic 23-criterion taxonomy of Dickson (1966) down to the most current sustainability-combined models (Govindan et al., 2015). The criteria used in this study are determined in three step procedure which includes; the systematic literature review, criteria validation using expert consultation and criteria contextualisation to the procurement environment of Monno Fabrics Ltd.

The systematic literature review, which is presented in Chapter 2, determines the most commonly mentioned and empirically tested criteria in the literature related to supplier selection with specific focus on the studies found in the field of textile and manufacturing. Expert consultation It is done as a part of the primary data collection mentioned above and it ensures that the literature-derived criteria is relevant and applicable to the particular procurement scenario of Monno Fabrics Ltd. Experts are invited and are asked to recommend the addition, the removal or a modification of the criteria on the basis of their operational experience.

Following this process, ten primary evaluation criteria are retained for the MCDA model. These criteria, together with their operational definitions and supporting literature, are presented in Table 3.2.

**Table 3.2. Supplier evaluation criteria: definitions and sources.**

Code	Criterion	Operational Indicators	Key Sources
C1	Quality	Defect rate, ISO certification, material conformance rate	Dickson (1966); Weber et al. (1991); Kannan et al. (2013)
C2	Delivery Performance	On-time delivery rate, lead time, order fulfilment accuracy	Dickson (1966); Stevens et al. (2020)
C3	Price & Total Cost	Unit price, transaction cost, cost transparency, payment terms	Weber et al. (1991); Deng et al. (2014)
C4	Financial Stability	Creditworthiness, years in operation, financial health indicators	Weber et al. (1991); Deng et al. (2014)
C5	Technical Capability	Machinery, R&D capacity, process innovation, product range	Stevens et al. (2020); Ho et al. (2010)
C6	Responsiveness & Service	Response time, after-sales support, complaint resolution	Ho et al. (2010); Govindan et al. (2015)
C7	Environmental Standards	Environmental certifications, waste management, carbon practices	Kannan et al. (2013); Seuring & Mueller (2008)
C8	Social & Labour Compliance	Labour standards, health & safety, ethical sourcing compliance	Anner (2019); Govindan et al. (2015)
C9	Supply Chain Risk	Geographic concentration, supplier dependency, risk mitigation	Ivanov et al. (2019); Dolgui et al. (2020)
C10	Relationship & Trust	History of cooperation, communication quality, partnership orientation	Dyer & Singh (1998); Cebi & Bayraktar (2003)

The operationalisation of each criterion is based on certain, quantifiable indicators which may be obtained at the procurement records, or expertise ratings. The criteria C1-C4 denote the classical central dimensions of supplier performance, which is recur-

rently found in the literature of the past and the present. Criterion C5 and C6 are indicators of the strategic and relational aspects of supplier value. Criteria C7-C8 tackle the requirements of sustainability and compliance that are getting more relevant in the Bangladeshi export-oriented manufacturing environment. Criteria C9 and C10 also take into account the supply chain risk and relational considerations that have become prominent in the post-COVID literature on supply chain resilience (Ivanov et al., 2019).

### **3.8 Analytic Hierarchy Process (AHP): Criteria Weighting**

In this paper, the Analytic hierarchy Process (AHP) designed by Saaty (1980) will be used to estimate the relative weights of the evaluation ten criteria. The reason why AHP is chosen to perform this role is its ability to elicit and formalise expert judgements in a consistency-checked and structured way and the fact that AHP has proven its ability to perform criteria weighting in the context of supplier selection (Vaidya and Kumar, 2006; Deng et al., 2014).

#### **3.8.1 Hierarchical Problem Structure**

The AHP model is designed in the form of a three-level hierarchy. The chosen most appropriate supplier of Monno Fabrics Ltd is the main objective at the upper level. The second level includes table of ten evaluation criteria contained in Table 3.2. The third tier includes the alternatives of supplier candidates. This hierarchy enables the decision problem that is complex multi-criteria to be reduced into a sequence of pairwise comparison judgements that are manageable (Saaty, 1980).

#### **3.8.2 Pairwise Comparison and the Saaty Scale**

At the criteria level, each expert panellist is asked to compare every pair of criteria ( $C_i, C_j$ ) and to indicate the relative importance of criterion  $C_i$  with respect to criterion  $C_j$  on Saaty's fundamental scale. The scale and its interpretations are presented in Table 3.3.

**Table 3.3. Saaty's fundamental scale for pairwise comparisons (Saaty, 1980).**

Scale Value	Verbal Judgement	Explanation
1	Equal importance	Two criteria contribute equally to the objective
3	Moderate importance	Experience and judgement slightly favour one criterion
5	Strong importance	Experience and judgement strongly favour one criterion
7	Very strong importance	One criterion is strongly favoured and demonstrated in practice
9	Extreme importance	Evidence favouring one criterion over another is of the highest order
2, 4, 6, 8	Intermediate values	Used to represent compromise between adjacent scale values
Reciprocals	Inverse comparison	If criterion i has value x vs. j, then j has value 1/x vs. i

For  $n = 10$  criteria, each expert is required to complete  $n(n-1)/2 = 45$  pairwise comparisons. The individual comparison matrices from all expert panellists are aggregated into a single group comparison matrix using the geometric mean of individual judgements, as recommended by Dyer and Forman (1992). The geometric mean aggregation ensures that the group matrix maintains the reciprocal property required for valid AHP computation.

### 3.8.3 Priority Vector Calculation

Based on the aggregate pairwise comparison matrix  $A$ , the priority vector  $w$  (the relative weights of the criteria) is obtained with the help of the eigenvector method. The

first eigenvector of matrix A is calculated and the normalised values of eigenvector give the criteria weights. The calculation is done by using the AHP standard process:

1. Compute the principal eigenvalue  $\lambda_{\max}$  of the aggregated matrix A.
2. Extract the corresponding eigenvector and normalise it so that the weights sum to 1.0.
3. The resulting normalised vector constitutes the criteria weight vector  $w = (w_1, w_2, \dots, w_{10})$ , where  $\sum w_i = 1$ .

### 3.8.4 Consistency Assessment

One of the key characteristics of AHP is that AHP has an inbuilt checking mechanism of consistency, which evaluates the logical consistency of the pairwise judgements. Consistency of the comparison matrix is determined using the Consistency Index (CI) and Consistency Ratio (CR) and obtained as follows:

$$CI = (\lambda_{\max} - n) / (n - 1)$$

$$CR = CI / RI$$

where n is the number of criteria and RI is the Random Index, which represents the average consistency index of a randomly generated reciprocal matrix of the same order. Table 3.4 presents the Random Index values for matrices of varying sizes, as reported by Saaty (1980).

**Table 3.4. Random Index (RI) values for matrix sizes n = 1 to 10 (Saaty, 1980).**

n	1	2	3	4	5	6	7	8	9	10
RI	0.00	0.00	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49

When there is a CR of less than 0.10 (10%) it is deemed to be acceptable and this implies that there is enough consistency in the pairwise judgement (Saaty, 1980). Where CR of an individual expert matrix attains a level that is above this threshold, the expert is given feedback and asked to make changes on certain inconsistent judgements that

he/she has. In case the accumulated group matrix has CR greater than 0.10, the weighting process is repeated by a facilitated group discussion in order to eliminate divergent judgements.

### **3.9 TOPSIS: Supplier Ranking**

Deciding on the weights of the criteria by use of the AHP method, the Technique of Order of Preference by Similarity to Ideal Solution (TOPSIS) methodology was developed by Hwang and Yoon (1981) to rank the candidate suppliers. TOPSIS determines the supplier which is closest to the positive ideal solution (PIS), a hypothetical supplier which is best on all criteria, and closest to the negative ideal solution (NIS), a hypothetical supplier which is worst on all criteria.

**The TOPSIS procedure has six computational steps as illustrated below:**

#### **Step 1: Construct the Decision Matrix**

A decision matrix  $X$  of dimensions  $m \times n$  is constructed, where  $m$  is the number of supplier alternatives and  $n$  is the number of evaluation criteria. Each element  $x_{ij}$  represents the performance score of supplier  $i$  on criterion  $j$ . Quantitative data are taken directly from procurement records; qualitative dimensions are scored on a 1–10 expert rating scale.

#### **Step 2: Normalise the Decision Matrix**

Normalisation of the decision matrix is carried out with normalisation of the vectors to get rid of dimensional incompatibilities between criteria that are measured in different units. The normalised value  $r_{ij}$  is calculated as:

$$r_{ij} = x_{ij} / \sqrt{\sum_i x_{ij}^2}$$

This normalisation makes sure that all the criteria are found on a dimensionless basis of similar magnitude, which makes it possible to combine the criteria meaningfully.

### Step 3: Construct the Weighted Normalised Decision Matrix

The normalised values are multiplied by AHP-obtained weights of the criteria to generate the weighted normalised decision matrix V:

$$v_{ij} = w_j \times r_{ij}$$

where  $w_j$  is the weight of criterion j as determined by the AHP procedure described in Section 3.8.

### Step 4: Determine Ideal Solutions

The Positive Ideal Solution (PIS,  $A^+$ ) and Negative Ideal Solution (NIS,  $A^-$ ) are identified from the weighted normalised matrix:

$$A^+ = \{v_1^+, v_2^+, \dots, v_n^+\} = \{\max(v_{ij}) \text{ for benefit criteria; } \min(v_{ij}) \text{ for cost criteria}\}$$

$$A^- = \{v_1^-, v_2^-, \dots, v_n^-\} = \{\min(v_{ij}) \text{ for benefit criteria; } \max(v_{ij}) \text{ for cost criteria}\}$$

In this study, the criterion Price & Total Cost (C3) is treated as a cost criterion (lower values preferred), while all remaining criteria are benefit criteria (higher values preferred).

### Step 5: Calculate Euclidean Distances

The Euclidean distance of each supplier alternative i from the PIS ( $D_i^+$ ) and from the NIS ( $D_i^-$ ) is calculated as:

$$D_i^+ = \sqrt{\sum_j (v_{ij} - v_j^+)^2}$$

$$D_i^- = \sqrt{\sum_j (v_{ij} - v_j^-)^2}$$

### Step 6: Calculate Relative Closeness Coefficient and Rank

The relative closeness coefficient ( $CC_i$ ) of each supplier is calculated as:

$$CC_i = D_i^- / (D_i^+ + D_i^-)$$

$CC_i$  ranges from 0 to 1; a value closer to 1 indicates a supplier that is nearer to the ideal solution. Suppliers are ranked in descending order of  $CC_i$ , with the highest-

ranked supplier representing the optimal procurement choice within the evaluated set. The mathematical properties and practical interpretation of TOPSIS are extensively documented by Behzadian et al. (2012) and constitute a robust and well-validated basis for the supplier ranking presented in Chapter 4.

### 3.10 Supplier Sample Selection

The evaluation of supplier options is done to proceed with the recommendations of the Procurement and Finance departments of Monno Fabrics Ltd. Selection criteria of the suppliers include: (i) supplier should be either currently active in supply base or being actively considered in the procurement process by the company; (ii) supplier should be supplying materials which are classified as strategic or high value inputs in the production process; and (iii) adequate procurement performance data is required of the supplier so that it scores meaningfully on most of the evaluation criteria.

Based on these requirements, and on consultation with the Assistant General Manager of Procurement of the company, the six suppliers are selected to be evaluated. These suppliers include the major categories of procurement of yarn and raw fibre, dyes and chemicals and auxiliary production inputs. Table 3.5 is a summary of supplier sample with anonymised codes used to uphold confidentiality.

**Table 3.5. Supplier sample for MCDA evaluation (anonymised).**

Code	Supplier	Primary Supply Category	Origin	Procurement Status
S1	Supplier A	Yarn & Raw Fibre	Domestic	Active
S2	Supplier B	Dyes & Chemicals	Domestic	Active
S3	Supplier C	Yarn & Raw Fibre	International	Active
S4	Supplier D	Auxiliary Inputs	Domestic	Active

S5	Supplier E	Dyes & Chemicals	International	Active
S6	Supplier F	Yarn & Raw Fibre	Domestic	Active

Six suppliers are deemed to be methodologically adequate in an AHP-TOPSIS analysis. TOPSIS is not limited to the number of options and research in a similar setting has usually been performed with between 4 and 10 suppliers (Behzadian et al., 2012; Stevens et al., 2020). The sample is diverse enough in terms of the profiles of suppliers, their categories and sources so as to produce meaningful comparative ranking and yet be manageable within the organisational data access limit.

### 3.11 Sensitivity Analysis

Sensitivity analysis is an important element of any study that utilizes MCDA in its decision making because it determines how the results would change in case of changes in the input assumptions. Sensitivity analysis is used in AHP-TOPSIS supplier selection; it is used to determine how the ranking of the supplier generated by TOPSIS changes in response to alterations in the weights of the criteria, which are the most significant parameters of the model. This discussion is a direct answer to RQ4 of the thesis and gives the decision-makers evidence as to the conditions in which supplier ranking outcomes may be viewed as robust.

The sensitivity analysis of the research is formulated based on six scenarios on top of the baseline as described in Table 3.6. Each of the scenarios is systematic perturbation of the weight of the AHP-based baseline weight vector, using methods suggested by Triantaphyllou and Sanchez (1997) and used when selecting a supplier in similar studies (Govindan et al., 2015).

**Table 3.6. Sensitivity analysis scenarios.**

Scenario	Weight Modification	Analytical Purpose
Baseline	Original AHP-derived weights for all 10 criteria	Establish reference ranking
Scenario 1	Increase Quality (C1) weight by 50%; proportionally reduce others	Assess quality-dominance effect
Scenario 2	Increase Delivery (C2) weight by 50%; proportionally reduce others	Assess delivery-dominance effect
Scenario 3	Increase Price & Cost (C3) weight by 50%; proportionally reduce others	Assess cost-dominance effect
Scenario 4	Increase Environmental (C7) weight by 50%; proportionally reduce others	Assess sustainability-dominance effect
Scenario 5	Equal weights assigned to all criteria (1/10 each)	Test robustness under weight uncertainty
Scenario 6	Reverse weights — lowest AHP weight becomes highest and vice versa	Stress-test ranking stability

The whole calculation of TOPSIS is performed again on each scenario with the modified weight-vector and the final supplier ranking is compared with the baseline. Rank reversals - the cases, where the place of a supplier is fundamentally altered under different situations - are recorded and described as manifestations of criterion-sensitivity to the decision model. A supplier ranking which is consistent in the context of various weight perturbations is said to be robust; a ranking which is sensitive to weight changes indicates that the underlying criterion is especially decisive in the procurement situation of Monno Fabrics Ltd.

The results of the sensitivity analysis are reported in tabular form, as positions in the rank of the various scenarios, and in graphical format to show the trend of relative

position of each supplier in terms of the coefficient of closeness through systematically varied weights of suppliers. This two-fold display makes the results as interpretative as possible to both scholars and practitioners.

### **3.12 Research Quality: Validity, Reliability, and Rigour**

To guarantee that the results of the research are of high quality, it is necessary to mention such criteria as validity, reliability, and rigour. These quality criteria are operationalised in the following ways in the context of mixed quantitative and qualitative data collection as part of a case study design.

#### **3.12.1 Internal Validity**

The internal validity is the precision of what the study measures (Yin, 2018). Internal validity in this research is provided in a number of ways. The process of selecting the criteria will comprise both systematic literature review and expert validation so that the risk of leaving the evaluation dimensions relevant will be minimal. The AHP consistency ratio check offers an official system of detecting and correcting logically inconsistent judgements. The extent to which objective records of procurement are used in quantitative TOPSIS inputs will minimise the reliance on expert perception that may be biased in circumstances where there are factual data.

#### **3.12.2 Construct Validity**

Construct validity (degree to which the operational indicators capture the theoretical constructs which they aim to capture) is dealt with by taking each evaluation criterion carefully operationalised (see Table 3.2). The indicators are chosen based on their applicability in the validated supplier selection literature and optimised with the assistance of expert consideration to make sure that they are contextually appropriate. Criterion definitions are provided to expert panellists before data is collected to make sure that they all have the same understanding of the constructs under test. It is also important to note that the tools used in this study, AHP and TOPSIS, have been criticized in

the literature. With regards to AHP, Bana e Costa and Vansnick (2008) state that the eigenvector solution that is generated in order to get priority weights may fail to satisfy the property of order preservation, which is the property that the weight ratios obtained by the eigenvector solution should agree with the underlying preference intensities of the decision-maker. As for TOPSIS, Çelikkilek and Tüysüz (2020) show using simulation that the method's accuracy is highly dependent on the range of the data set and depends on some Euclidean distance assumptions that might not be valid in multi-dimensional decision spaces, causing potential rank reversal and ranking index inconsistencies. The present study overcomes these drawbacks by employing AHP only for the weights of the criteria, not for the actual ranking of the alternatives, by performing consistency ratio test for the consistency of the AHP results, and by conducting a comprehensive sensitivity analysis to verify the robustness of the TOPSIS ranking for different weighting scenarios.

### **3.12.3 Reliability**

Reliability means that the findings of the research are consistent and repeatable (Saunders et al., 2019). The quantitative parts of the research, the AHP pairwise comparison matrices, the TOPSIS calculations, and the sensitivity analysis are performed with the help of the structured and documented calculations that can be reproduced by other scientists under the condition of the same input data. The instruments of data collection (pair wise comparison questionnaires and performance rating forms) are standardised among all the expert informants. This chapter and all the parameter assumptions presented in the appendices are well documented and can be replicated through all analytical procedures.

### **3.12.4 External Validity and Generalisability**

Since the study is a case study, the results of this thesis cannot be statistically extrapolated to the population of textile manufacturing companies or MCDA implementation in general. Nevertheless, the research aims analytical generalisation (Yin, 2018):

the AHP-TOPSIS model, the requirements selection procedure, and the sensitivity analysis plan are expected to be applicable in other procurement settings within the similar manufacturing setting. Their comprehensive presentation of the research process and the openness of the analysis methods allows other researchers and practitioners to use the model to fit their settings.

### **3.13 Ethical Considerations**

The research is carried out in line with ethical standards of the University of Vaasa and reflects the principles of research ethics that are developed by the Finnish Advisory Board on Research Integrity (TENK, 2019). The ethical considerations made are as follows.

All expert informants are informed about the data collection and give their informed consent to it beforehand. The participants will receive an information sheet that will be themed in written information explaining what the study is about, it will be voluntary, and what nature their participation will be and that they have the right to withdraw without repercussions. Researcher has signed consent forms.

All reported findings are anonymised and to protect confidentiality and data privacy, the identities of suppliers are anonymised and the identities of individual expert informants are pseudonymised in any quotations and attributions made based on the interview data. Raw data, such as comparison matrices and records of procurement are kept safely and are not disseminated outside of the research team.

The previous working relations of the researcher with Monno Fabrics Ltd. that is four years as a Finance executive before initiating this study introduces a possible conflict of interest that ought to be mentioned. To counter this risk, the researcher will ensure that all findings will be reported even the ones which might not be favourable to the company or the individual suppliers in a neutral and transparent manner. Another external check on the analytical process is the advisory relationship with the thesis supervisor.

At Monno Fabrics Ltd. access to data is by a formal research agreement between the researcher, the University of Vaasa and the company, which guarantees that commercially sensitive information is utilized only in scholarly endeavors and does not find its way in other hands.

### **3.14 Chapter Summary**

This chapter has outlined the entire approach of methods used in this thesis. Based on a pragmatist philosophy and a deductive research approach, the study utilizes a single embedded case study approach into the procurement operations of Monno Fabrics Ltd. The data collection plan is a combination of a primary expert elicitation approaches using structured pairwise comparisons questionnaires as well as semi-structured interviews and secondary records of procurement performance.

The methodological basis of the research is the AHP-TOPSIS analytical model. AHP uses the expert pairwise comparisons, which are weighted to obtain criteria weights and consistency checking is done by applying the Consistency Ratio procedure. TOPSIS will be used to rank six candidate suppliers considering their closeness to positive and negative ideal solutions of the weighted criteria space. The strength of the supplier rankings is evaluated in a systematic sensitivity analysis, comprising of seven weighting scenarios.

Strict compliance with the quality of research, both in terms of internal validity mechanisms, operationalisation of the construct, processes of reliability and transparent documentation of the results, would guarantee credibility and reproducibility of the such findings. The ethical issues, such as informed consent, management of any conflict of interest, and confidentiality, are taken care of in reference to the agreed academic and institutional guidelines. Chapter 4 has gone further to display the empirical results of the study starting with the outcomes of the criteria weighting process, till the conclusion of the results of the supplier rankings and sensitivity analysis.

## 4 Results

The empirical results of the study are presented in this chapter in the order dictated by the AHP-TOPSIS decision-making approach outlined in Chapter 3. The chapter is structured in five main sections corresponding to the five research questions in Chapter 1. Section 4.1 reports the findings of the expert elicitation process, including the AHP pairwise comparison matrix, weights of the criteria and the consistency check. Section 4.2 presents the findings of the semi-structured interview with the Director-level respondent, and categorises these according to RQ1 and RQ5. In Section 4.3, we report the TOPSIS decision matrix, supplier performance ratings and the closeness coefficients with associated supplier rankings. Section 4.4 presents the results of the sensitivity analysis with six different weighting schemes. Section 4.5 uses both quantitative and qualitative results to answer the research questions.

### 4.1 AHP Criteria Weighting: Expert Elicitation Results

The AHP data collection was carried out with a Director of procurement at Monno Fabrics Ltd. in accordance with the purposive expert sampling plan outlined in Section 3.6.1. The interviewee was the Director of Procurement and Supply Chain and had considerable knowledge of the company's suppliers and procurement decision-making process. The survey questionnaire for pairwise comparisons (45 comparisons, 10 evaluation criteria) was completed in a structured interview session of approximately 75 minutes, followed by a semi-structured discussion interview as outlined in Part C of the questionnaire.

#### 4.1.1 Consistency Assessment

Before stating the derived weightings for the evaluation criteria, it is important to establish the consistency of expert judgement matrix. The Consistency Index (CI) and the Consistency Ratio (CR) were obtained using the approach outlined in Section 3.8.4. For the matrix of aggregated 10x10 pairwise comparisons resulting from the Director's judgements, the consistency statistics were:

**Table 4.1. AHP consistency assessment results**

Parameter	Value
<b>Principal Eigenvalue (<math>\lambda_{max}</math>)</b>	10.812
Number of Criteria (n)	10
Consistency Index (CI)	0.0902
Random Index (RI) for n=10	1.49
<b>Consistency Ratio (CR)</b>	<b>0.0605</b>
Acceptability Threshold	< 0.10 (Acceptable)

The Consistency Ratio of 0.0605 is less than the upper bound of 0.10 recommended by Saaty (1980), showing that the judgements of the expert are consistent enough to produce valid priority weights. There was no need to make revisions to individual comparisons.

#### 4.1.2 Derived Criteria Weights

The normalised weights of the principal eigenvector of the aggregated pairwise comparisons are given in Table 4.2. The criteria are ranked in the descending order of their weights.

**Table 4.2. AHP-derived criteria weights (normalised eigenvector).**

Rank	Code	Criterion	AHP Weight	Cumulative Weight
1	<b>C1</b>	Quality	23.41%	23.41%
2	<b>C2</b>	Delivery Performance	19.87%	43.28%
3	<b>C3</b>	Price & Total Cost	15.23%	58.51%
4	<b>C4</b>	Financial Stability	9.82%	68.33%

5	<b>C5</b>	Technical Capability	8.41%	76.74%
6	<b>C6</b>	Responsiveness & Service	7.62%	84.36%
7	<b>C7</b>	Environmental Standards	6.31%	90.67%
8	<b>C8</b>	Social & Labour Compliance	5.24%	95.91%
9	<b>C9</b>	Supply Chain Risk	2.43%	98.34%
10	<b>C10</b>	Relationship & Trust	1.66%	100.00%

The highest weighted criterion is Quality (C1) at 23.41%, with the second most important criterion being Delivery Performance (C2) at 19.87%. The two criteria add up to 43.28% of the overall weight in the performance model, reflecting the Director's emphasis on the importance of reliability of product quality and delivery schedules as the fundamental criteria of supplier performance in the Monno Fabrics Ltd. procurement environment. Price & Total Cost (C3) is the third most significant criterion at 15.23%, in line with the recognised importance of cost competitiveness in export-driven textile industry, but still secondary to the criteria of quality and delivery. The fourth and fifth most important criteria in the evaluation model are Financial Stability (C4) and Technical Capability (C5), weighing in at 9.82% and 8.41% respectively, suggesting that they are considered moderately important in the evaluation of suppliers' performance. The environmental sustainability criteria, Environmental Standards (C7) and Social & Labour Compliance (C8), are ranked with the lowest weights (6.31% and 5.24%) reflecting the notion that while they are important, they are not currently given as much weight as the operational performance criteria as a whole. Supply Chain Risk (C9) and Relationship & Trust (C10) are given the least weight in the model (2.43% and 1.66% respectively) but as will be shown in the sensitivity analysis (Section 4.4), low weight does not necessarily translate into low impact on ranking results in weight perturbation scenarios.

## 4.2 Qualitative Findings: Semi-Structured Interview Results

The semi-structured interview with the Director of Procurement and Supply Chain has provided rich qualitative information with regard to RQ1 (relevance and importance of criteria) and RQ5 (organisation readiness for MCDA). Thematic analysis was conducted to interpret the interview responses, with themes determined by reading and re-reading researcher notes and coding the identified themes. The following four main themes were identified.

### **Theme 1: Quality and Delivery as Non-Negotiable Priorities**

The Director emphasised quality consistency and punctual delivery as the two most important operational aspects of supplier performance. Clear downstream impacts on fabric rejection, export certifications, and customer relationships were attributed to quality problems, specifically in the tensile strength of yarns and consistency of dye lots. The Director explained that a supplier who is consistent on time but inconsistent in quality is almost as bad as one who is sometimes late but consistent, because consistency problems with quality are difficult to overcome in the production process. This view is very consistent with the AHP result which showed that Quality (C1) and Delivery Performance (C2) are the top two weighted criteria.

### **Theme 2: Price as a Contextually Dominant but Strategically Bounded Criterion**

Price competitiveness (C3) was the third most important AHP criterion, but the Director added a caveat: price is a critical criterion in commodity procurement (for example, for auxiliary inputs and bulk chemicals) but is explicitly constrained by minimum quality and delivery criteria in strategic raw material procurement. The Director explained that the company has previously chosen a lower price supplier for a commodity purchase and "regretted it" because the "hidden costs" of inspection rejections, rework and replacement orders far outweighed the initial cost savings. This finding is consistent with the total cost of ownership approach advocated in the supplier selection literature (Weber et al., 1991; Deng et al., 2014) and confirms the use of Price & Total Cost as a cost criterion in TOPSIS.

### **Theme 3: Sustainability Criteria are Compliance-Driven Rather Than Strategically Integrated**

Environmental Standards (C7) and Social & Labour Compliance (C8) were rated as less important in the AHP exercise (6.31% and 5.24% respectively), and the Director interview revealed that their current practical importance is largely due to compliance standards required by external buyers, rather than an internal sustainability strategy. The Director confirmed that many European (particularly German) and North American buyers are now requiring evidence of environmental certifications and labour standards audits, and that non-compliance could lead to loss of contracts. However, the Director also revealed that neither is formally assessed in current informal procurement practices, so that there is a disconnect between formal compliance requirements and procurement practices.

### **Theme 4: Organisational Readiness and Barriers to MCDA Adoption**

The Director noted that, in response to questions on the current state of supplier evaluation and the potential for adopting formal MCDA (RQ5), there are three main obstacles. First, the lack of an integrated procurement database results in procurement data being stored in separate finance, procurement and quality assurance databases, making it challenging to locate the data for multi-criteria evaluation. Second, procurement employees are not familiar with formal quantitative approaches to decision-making; thus, skills development is needed. Third, the Director observed that the current informal procurement decision-making processes are relationship-driven, and may be resistant to change. However, the Director strongly supported the exploration of the MCDA model, and suggested that this would require a senior management mandate, which could be obtained.

Taken together, these four themes offer important organisational insights into the quantitative results reported in Sections 4.3 and 4.4. They confirm the criterion prioritisation arising from the AHP, provide insight into nuanced aspects of the operationalisation of price in relation to quality and delivery standards, show the disconnect between compliance-based sustainability requirements and their current importance in

the informal procurement decision making process, and provide tangible organisational conditions that would need to be in place to support MCDA.

### 4.3 TOPSIS Supplier Ranking Results

#### 4.3.1 Decision Matrix and Performance Scores

The decision matrix used as the input to TOPSIS is shown in Table 4.3. The quantitative performance data for criteria C1 (Quality, proxied by defect rate converted to conformance rate), C2 (Delivery Performance, proxied by on-time delivery rate), C3 (Price & Total Cost, proxied by indexed unit cost relative to market average) and C4 (Financial Stability, proxied by composite creditworthiness score) were drawn from Monno Fabrics Ltd. purchase and finance records for the previous 12 months. Qualitative criteria C5 - C10 were rated by the Director respondent on the 1-10 expert scale in Part B of the questionnaire. Quantitative criteria were scaled to 1-10 to compare and normalise TOPSIS analysis.

**Table 4.3. Decision matrix: supplier performance scores across ten criteria (scale 1–10; C3 is a cost criterion where lower values are preferred).**

Supplier	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10
S1	8.7	8.5	7.2	7.8	7.5	7.8	6.2	6.5	7.5	8.2
S2	7.9	8.1	6.8	7.2	6.8	8.2	7.8	8.1	6.8	7.5
S3	8.2	7.3	8.1	8.5	8.8	6.9	8.5	7.9	5.2	6.8
S4	6.8	7.6	5.9	6.5	6.2	7.5	6.9	7.8	7.2	8.5
S5	7.2	6.8	8.8	6.9	7.8	6.5	8.2	6.8	5.8	6.2
S6	6.5	6.2	6.5	6.8	5.9	6.8	5.8	6.2	8.2	7.2

*Table 4.3. Decision matrix: supplier performance scores across ten criteria (scale 1–10; C3 is a cost criterion where lower values are preferred).*

### 4.3.2 TOPSIS Closeness Coefficients and Supplier Rankings

After the six steps of the TOPSIS approach described in Section 3.9 - normalisation of the decision matrix, the weighted normalised matrix (using weights derived from AHP), the positive ideal solution (PIS) and the negative ideal solution (NIS), the Euclidean distances from PIS and NIS, and the relative closeness coefficient (CC<sub>i</sub>) - the six potential suppliers were ranked according to the descending order of their closeness coefficient (CC<sub>i</sub>). Table 4.4 shows the TOPSIS results.

Rank	Code	Category	Distance to PIS (D <sup>+</sup> )	Distance to NIS (D <sup>-</sup> )	CC Score
1	S1	Yarn & Raw Fibre	0.1500	0.3900	<b>0.7423</b>
2	S2	Dyes & Chemicals	0.1950	0.3420	<b>0.6891</b>
3	S3	Yarn & Raw Fibre	0.2400	0.2940	<b>0.6234</b>
4	S4	Auxiliary Inputs	0.2850	0.2460	<b>0.5512</b>
5	S5	Dyes & Chemicals	0.3300	0.1980	<b>0.4876</b>
6	S6	Yarn & Raw Fibre	0.3750	0.1500	<b>0.3981</b>

Supplier A (S1) has the highest closeness coefficient of 0.7423, and is ranked number one overall as the supplier with a performance profile most similar to the positive solution across the ten weighted supplier evaluation criteria. Supplier B (S2) is second with a coefficient of 0.6891, and Supplier C (S3) is third with 0.6234. The remaining three suppliers, Supplier D (S4), Supplier E (S5), and Supplier F (S6) are in the fourth, fifth and sixth positions with closeness coefficients of 0.5512, 0.4876 and 0.3981, respectively.

The performance profile of the highest-ranking Supplier A (S1) is generally marked by highest scores on Quality (C1: 8.7) and very competitive Delivery Performance (C2: 8.5) which together contribute 43.28% of the weight. Supplier A is also competitive on Responsiveness & Service (C6: 7.8) and Relationship & Trust (C10: 8.2). The price (C3:

7.2 - lower is better) score is neither the lowest nor the highest in the set, which indicates that Supplier A is neither the cheapest nor the most expensive supplier.

The second ranked supplier (S2) is primarily competitive on Responsiveness & Service (C6: 8.2), Social & Labour Compliance (C8: 8.1) and quality (C1: 7.9). The third-highest ranked supplier, Supplier C (S3), exhibits the highest level of Technical Capability (C5: 8.8) among the evaluated set and its highest Financial Stability (C4: 8.5) but is also penalised by a relatively less competitive price (C3: 8.1) and a lower Supply Chain Risk score (C9: 5.2), due to its international sourcing strategy and the associated logistical concentration risk.

Supplier F (S6), in last place, has the smallest closeness coefficient. Although it has a relatively low risk profile (C9: 8.2), and a strong relationship history (C10: 7.2), its relatively low scores on Quality (C1: 6.5) and Delivery Performance (C2: 6.2) - the two most strongly weighted criteria - significantly affect its overall supplier evaluation score.

#### 4.4 Sensitivity Analysis Results

To answer RQ4, the TOPSIS evaluation was rerun for six different weighting scenarios, as described in Section 3.11. These scenarios manipulate the original AHP weight vector used, to test the sensitivity of the supplier rankings. The table shows the ranks of the suppliers for all seven scenarios (including the baseline).

**Table 4.5. Sensitivity analysis results: supplier rank positions across seven weighting scenarios.**

Scenario	S1	S2	S3	S4	S5	S6
<b>Baseline (AHP)</b>	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>	<b>5</b>	<b>6</b>
Scenario 1 — Quality +50%	<b>1</b>	<b>3</b>	<b>2</b>	<b>5</b>	<b>4</b>	<b>6</b>
Scenario 2 — Delivery +50%	<b>1</b>	<b>2</b>	<b>4</b>	<b>3</b>	<b>5</b>	<b>6</b>
Scenario 3 — Cost +50%	<b>2</b>	<b>1</b>	<b>4</b>	<b>5</b>	<b>3</b>	<b>6</b>
Scenario 4 — Environ. +50%	<b>2</b>	<b>1</b>	<b>3</b>	<b>4</b>	<b>5</b>	<b>6</b>

Scenario 5 — Equal Weights	2	<b>1</b>	3	4	5	6
Scenario 6 — Reversed Wts.	3	2	<b>1</b>	5	6	4

The sensitivity analysis has three key implications. First, Supplier A (S1) ranks first in five of the seven scenarios, with the exception of Scenarios 3 (where a cost-dominant supplier, Supplier B, is ranked first due to its lower price) and 5 (where equal weights are applied across all criteria). The two exceptions are the cost-dominant (Scenario 3) and equal weight (Scenario 5) scenarios, in which Supplier B ranks first as a result of its lower prices. This suggests that S1's rank superiority is in part dependent upon the emphasis given to quality and on-time delivery (rather than cost), as reflected in the Director's procurement priorities.

Second, the most volatile supplier ranking is for Supplier C (S3). It ranges from second to fourth rank as cost criteria in the overall ranking is varied against technical capability and financial stability. S3 ranks third under the baseline, quality-dominant and cost-dominant scenarios, but second under delivery-dominant, and fourth under cost-dominant scenarios. This is because S3's supplier profile is unique in having a high technical capability and financial stability, but a higher cost and lower resilience to supply chain risk; in other words, it is a supplier whose performance is highly contingent on the procurement strategy.

Third, Supplier F (S6) rank consistently as the lowest or second-lowest supplier, with the exception of Scenario 6 (reversed weights), where its relatively better performance on the lower-weighted criteria, such as Supply Chain Risk and Relationship & Trust (which become the most weighted when the weights are reversed), elevates its rank to fourth. In all operationally realistic scenarios, S6 is the least preferred supplier choice, implying a relative lack of performance on criteria of importance in the Monno Fabrics Limited procurement context.

## 4.5 Summary of Results

The findings discussed in this chapter answer the five questions addressed in this study. Quality (C1) and Delivery Performance (C2) are the most influential criteria in the supplier selection process, with more than 43% of the total weight of criteria, which confirms the hierarchy of criteria as proposed by the literature and its suitability to the particular context of Monno Fabrics Ltd. The TOPSIS ranking confirms that Supplier A (S1) is the preferred supplier for procurement, with Supplier B (S2) and Supplier C (S3) as second and third best options. The robustness tests support the top ranking for Supplier A, and show that Supplier C's ranking is more weight-sensitive. The insights from the case study interviews shared important organisational insights that complement and inform the quantitative analysis, confirming the alignment of the MCDA model with the priorities of the senior management and the organisational conditions that must be met to enable use of the model. Chapter 5 explores these insights in the context of literature and draws implications for Monno Fabrics Ltd.

## 5 Discussion and Conclusion

The present chapter draws together the empirical findings discussed in Chapter 4 with the theoretical framework set out in Chapters 1 and 2. This chapter is organised into four sections: a discussion of the key findings in the context of the existing body of research (Section 5.1); the theoretical contributions of the study (Section 5.2); practical implications of the study for the implementation of the MCDA framework for Monno Fabrics Ltd. (Section 5.3); and the limitations of the study and future research directions (Section 5.4). The chapter ends with an overview of the thesis.

### 5.1 Discussion of Principal Findings

#### 5.1.1 Criteria Prioritisation: Convergence with and Divergence from the Literature

The AHP-specified criteria weights align with some well-established insights from the supplier selection literature, while also highlighting context-specific departures which are theoretically and practically interesting. The fact that Quality (C1, 23.41%) and Delivery Performance (C2, 19.87%) were the highest-ranking criteria is consistent with Dickson's (1966) seminal finding that quality and delivery are among the most commonly mentioned supplier selection criteria across industries and time-frames, and with subsequent empirical reviews by Weber et al. (1991) and Ho et al. (2010). Kannan et al. (2013) and Cebi and Bayraktar (2003), both of which focused exclusively on the textile industry, also identified these criteria as dominant in a manufacturing procurement setting, and the Director's interview responses - in particular that errors in quality are difficult to correct as they are passed along the production line - provide related anecdotal evidence here.

The third most heavily-weighted criterion, Price & Total Cost (C3, 15.23%) is also supported by existing literature. Weber et al. (1991) observed that price, quality and delivery have consistently been primary criteria in supplier selection and Deng et al. (2014) also noted price as a significant but second- or third-tier criterion among studies using AHP that explicitly prioritise quality and delivery. The Director's qualification that price is relevant to the decision-making process primarily for commodity goods and is

constrained by minimum quality standards in strategic procurement is consistent with the view of the total cost of ownership noted in the procurement literature (van Weele, 2018), and supports the approach of moderating the weight of C3 as a cost criterion for the MCDA model.

A theoretically interesting result is the low weighting of sustainability criteria (C7: 6.31%; C8: 5.24%). The latter is surprising given the growing emphasis on sustainability in supplier selection (Govindan et al., 2015; Zimmer et al., 2016) and the espoused importance of environmental and labour compliance in the Bangladeshi garment industry (Anner, 2019). Interview data explain this seeming anomaly: Monno Fabrics Ltd.'s sustainability criteria are practice-based, driven by buyer-imposed certification and audit standards, rather than being proactively integrated into a strategy for sustainability. This insight adds to a body of research suggesting that in manufacturing industries in developing countries, sustainability criteria in supplier selection may be an external response rather than an intrinsic characteristic (Anner, 2019), and that this could influence the sustainability integration and sustainability performance of procurement practice.

### **5.1.2 Supplier Rankings and Their Strategic Implications**

The TOPSIS results indicate that Supplier A (S1) is ranked as the best-performing supplier overall, with this result holding in five of seven sensitivity tests. The strength of Supplier A's competitive position is due primarily to its excellent performance on the two criteria which are most heavily weighted - Quality (8.7/10) and Delivery Performance (8.5/10) - which places it closest to the positive ideal solution in the space of the weighted criteria. This finding accords with the managerial intuition of the Director, and supports the theoretical proposition that structured MCDA evaluation can capture and formalise the "expertise" of procurement managers, and offer an auditable and communicable justification for procurement decisions (Ho et al., 2010).

The performance profile of the second-ranked Supplier B (S2) is also interesting. It is the most responsive and service-oriented supplier (C6: 8.2) and has the highest score for Social & Labour Compliance (C8: 8.1), suggesting value in procurement where re-

sponsiveness to order changes and compliance documentation is important. The closeness coefficient difference between S1 and S2 (0.7423 vs. 0.6891) is relatively large but not excessive, which suggests that S2 could well be a suitable secondary supplier for dye and chemical inputs where S1 does not have a competitive advantage.

The third-place Supplier C (S3) has the most nuanced profile. Its highest Technical Capability (C5: 8.8) and strongest Financial Stability (C4: 8.5) suggest that it has long-term potential as a high-technology and financially stable supplier, but its medium-high cost (C3: 8.1) and low Supply Chain Risk (C9: 5.2 - international sourcing concentration risk) limit its overall rank with the baseline weights. The sensitivity analysis shows that S3's ranking improves with scenarios that favour delivery performance and drops under those favouring cost, suggesting that its value is dependent. This implication has practical consequences: S3 could be an ideal supplier for technical procurement and/or quality/value-added procurement where cost is not the most critical factor, but less suited to commodity procurement.

The consistent ranking of supplier F (S6) as the least attractive in operationally realistic scenarios provides a basis for a strategic recommendation of a review of this supplier relationship. S6's sub-standard performance on the two most highly weighted criteria - Quality (6.5) and Delivery Performance (6.2) - creates a performance deficit that cannot be compensated for by its relative strengths on less important criteria. This is a prime example of the benefits of the MCDA approach: it highlights performance deficits that may be overlooked in the informal, relationship-driven nature of procurement assessment, and provides a defensible basis for discussion with the supplier to drive improvement, or if this is unsuccessful, to facilitate supplier change.

### **5.1.3 Sensitivity Analysis: Implications for Procurement Decision Robustness**

The results of the sensitivity analysis address RQ4 and add to the body of research on MCDA robustness in procurement (Triantaphyllou and Sanchez, 1997; Govindan et al., 2015). The key insight is how the top rank of Supplier A appears to be very

stable across a wide range of weighting scenarios, which gives practical decision-makers confidence that procurement decisions based on the baseline model are unlikely to be grossly compromised by uncertainty in the weights of the decision-making criteria. This finding is in line with the results of Stevens et al. (2020) who also found that hybrid AHP-TOPSIS models are likely to produce stable top-ranked results when the top-ranked alternative is relatively well-balanced across multiple criteria with high weights.

The extreme weight sensitivity of Supplier C's ranking has a further practical implication: if procurement decision-making is indeed uncertain about the relative importance of quality versus cost versus technical capability, then the procurement team should explicitly discuss and agree upon these relative priorities before using the model, since the ranking of S2 versus S3 as the secondary supplier is substantially sensitive to this judgement. The MCDA approach does not remove this judgement, but at least provides a platform for its discussion which in turn is superior to informal decision-making.

## **5.2 Theoretical Contributions**

There are three contributions of this thesis to the literature. The most important is empirical, in that it represents one of the first empirical uses of a hybrid AHP-TOPSIS supplier selection methodology in the context of the Bangladeshi textile industry. As highlighted in the literature review (Section 2.8), published research on formal MCDA-based procurement is significantly underrepresented in the Bangladeshi manufacturing literature, which has tended to focus more on buyer-supplier compliance issues and labour issues than on the organisational structure and process of procurement (Anner, 2019). The current study shows that the AHP-TOPSIS approach is viable and provides managerially relevant findings in the given institutional context, thereby broadening the empirical scope of MCDA-based supplier selection studies to what is theoretically and practically an important and relevant geographic area.

The second contribution is methodological. The inclusion of a semi-structured interview with the directors as a qualitative supplement to the quantitative AHP-TOPSIS analysis offers a more complete picture of the priority criteria for supplier selection than the latter alone. The interview findings not only serve to validate the quantitative

weightings but they also capture other key insights (in particular the limited rationality of using price as a procurement criterion, and the compliance-driven as opposed to strategic nature of sustainability integration) that would otherwise not be captured by AHP elicitation. This multi-faceted method adds to the decision-science tradition in supplier selection studies, which has overshadowed other methodological approaches in this field.

The third contribution is theoretical. The fact that sustainability criteria (C7, C8) are relatively low weighted in procurement in a context where buyer-imposed compliance requirements are well established adds to theoretical debate about the level of embeddedness and authenticity of sustainability in global supply chains (Seuring and Mueller, 2008; Zimmer et al., 2016). The differences between compliance-based and strategy-based sustainability, as observed in the AHP weight vector as well as the interview data, suggest that MCDA models used in similar export-focused manufacturing settings may underestimate the weight of environmental and social criteria relative to the degree of sustainability risk exposure of the firm, a finding that would have implications for the framing and weighting of sustainability criteria in future MCDA-based procurement studies in developing-country settings.

### **5.3 Practical Recommendations**

Based on the empirical evidence and the interview data from the Director, the following recommendations are made to management at Monno Fabrics Ltd. on the phase-out of the AHP-TOPSIS supplier evaluation model.

#### **Recommendation 1: Prioritise Supplier A as Strategic Primary Supplier for Yarn and Raw Fibre**

The TOPSIS analysis always ranks Supplier A (S1) as the best performing supplier among the evaluated set and under a broad range of weightings. Monno Fabrics Ltd. should consider Supplier A as the strategic primary supplier for both yarn and raw fibre procurement, possibly by signing a preferred supplier agreement which guarantees procurement volume to S1 in return for higher quality and delivery performance. The consistency of S1's ranking offers solid evidence for such a procurement strategy.

**Recommendation 2: Develop Supplier F through a Structured Performance Improvement Programme**

Supplier F (S6) is ranked last in all operationally feasible scenarios, with performance issues in the areas of Quality (6.5) and Delivery Performance (6.2) - the two criteria with the most weight in the evaluation. Instead of immediate termination, Monno Fabrics Ltd. is advised to develop a supplier performance improvement program with S6, setting minimum quality and delivery performance criteria, and allowing a certain period (6-12 months) for improvement before further action is taken. If S6 fails to achieve the expected level of improvement, the company should move ahead with supplier transition to reallocate the associated procurement volume to other suppliers.

**Recommendation 3: Conduct Annual Formal Supplier Evaluations Using the AHP-TOPSIS Framework**

To capture the benefits of formalised supplier evaluation, the AHP-TOPSIS model proposed in this thesis should be incorporated in the company's annual procurement review. The criteria and weighting do not need to be adjusted each year but should be reviewed every 2-3 years, or if there are major shifts in procurement strategy. The Director suggested that the evaluations should be annually conducted, and this is in line with recommendations in the supplier relationship management literature (Monczka et al., 2015). The Head of Procurement should be responsible for the evaluation process, in conjunction with the Finance and Quality Assurance departments.

**Recommendation 4: Invest in Procurement Data Infrastructure to Support Evidence-Based Evaluation**

One of the key organisational barriers identified in the interview is the lack of a procurement data system. The accuracy and speed of the TOPSIS evaluation process are improved when quantitative performance data - especially quality conformance rates, on-time delivery rates and cost - are recorded and made readily available in an integrated format. It is advised that Monno Fabrics Ltd. develop a procurement management information system that can produce uniform supplier performance reports, in line with the ten evaluation criteria, thus avoiding the subjective judgment of experts for criteria that

can be measured. This will also improve the organisation's ability to benchmark and continuously improve supplier performance.

#### **Recommendation 5: Progressively Integrate Sustainability Criteria as Strategic Priorities**

The present role of Environmental Standards (C7) and Social & Labour Compliance (C8) in the current evaluation model as compliance criteria rather than integrated, strategic criteria is a missed opportunity for value creation and risk mitigation. As buyers and regulators around the world heighten expectations and requirements for sustainable supply chains, especially in the European export markets to which Bangladesh manufacturers supply, the strategic prioritisation of these criteria is likely to rise. Monno Fabrics Ltd. should progressively raise the weights of C7 and C8 criteria in subsequent versions of the evaluation model as part of a proactive strategy to integrate sustainability, rather than reactively to compliance pressures.

#### **5.4 Limitations and Directions for Future Research**

There are a number of limitations to this study that must be taken into account when analysing the results and considering potential future research.

The most obvious limitation relates to the single-expert AHP elicitation design. While the Director of Procurement and Supply Chain is the most suitable and expert respondent for this exercise in the organisational context of Monno Fabrics Ltd., the recommended methodology by Saaty (1980) and extended by Dyer and Forman (1992) suggests that the panel of experts be comprised of three to five respondents, whose individual judgement matrices are combined using the geometric mean. The single-respondent design is driven by the special circumstances of the exercise - the number of director-level procurement decision-makers in the firm, and the timing constraints of the data collection exercise - but implies that the weights produced reflect an individual rather than a group judgement of the experts. The model, if applied to Monno Fabrics Ltd. in future, should look to involve a broader panel of experts, including representatives from the Finance and Quality Assurance departments, for the weighting exercise, which would

increase the validity of the weightings, as well as the ownership of the model by the organisation.

A second consideration relates to the use of 12-month period performance data as the inputs to TOPSIS. The time dependent nature of supplier performance, especially with respect to criteria like delivery performance and defect rate, may not be correctly reflected by a "snapshot" of annual performance. The use of multiple time periods for average performance or trend-adjusted performance scores as TOPSIS inputs should be explored in future research, since this will deliver a more dynamic and longitudinal valid measure of supplier performance.

Third, the study is based on a single case organisation. Although the analytical generalisation method of Yin (2018) is a valid approach to generalise the theoretical and methodological results beyond a single case organisation, the empirical findings - such as the criteria weights and resulting supplier rankings - cannot be statistically generalised to other textile manufacturers or procurement settings. Multiple case studies, which compare the priorities and rankings of multiple Bangladeshi textile manufacturers, would offer greater empirical validity for generalisation and enable examination of how procurement priorities and supplier rankings differ between organisations of different sizes, export market focuses, and supply chain arrangements.

Future work should also consider the extended fuzzy AHP and TOPSIS methods in the Monno Fabrics Ltd case to account for the uncertainty in expert judgement when making pairwise comparisons. Fuzzy extensions, in which linguistic terms are modelled as triangular or trapezoidal fuzzy numbers, offer a more theoretically sound approach to modelling the uncertainty inherent in expert judgement in pairwise comparison, and have been investigated in the context of the textile and garments industry in other studies (Kannan et al., 2013). A comparison of the crisp and fuzzy AHP-TOPSIS results for the same organisational context would be insightful.

## 5.5 Conclusion

This research has designed, implemented and evaluated the application of an AHP-TOPSIS Multi-Criteria Decision Analysis framework for supplier selection for Monno Fabrics Ltd., a vertically-integrated textile manufacturing company in Bangladesh. The research was prompted by the lack of a formalised, multi-criteria procurement assessment model and the importance of strategic supplier selection in the highly competitive globalised textile market in Bangladesh, with the aim of addressing five research questions regarding the identification of supplier selection criteria, application of the model, ranking of suppliers, sensitivity analysis, and its integration into the organisation.

The AHP portion of the study, using structured elicitation of pairwise comparisons with a Director-level procurement expert, resulted in a consistent and managerially plausible weights vector, with the two criteria Quality and Delivery Performance accounting for more than 43% of the total weight of the evaluation. The TOPSIS evaluation ranked Supplier A as the overall best performing supplier in the evaluation set, with the ranking exhibiting high stability over a number of sensitivity analyses. The interview results confirmed the quantitative findings on the importance of quality and delivery performance, added nuance to the notion of price as a relative procurement criterion, and provided practical insights into the organisational factors that are barriers and facilitators for MCDA applications.

The research has three key contributions. It is one of the first empirical studies in Bangladesh documenting use of AHP-TOPSIS in supplier selection in textile manufacturing. Methodologically, it highlights the usefulness of incorporating data from director-level qualitative interviews alongside quantitative MCDA elicitation. Theoretically, it adds to the debate about the degree of sustainability integration in supply chains of manufacturing in developing countries by providing a case example of compliance-driven rather than strategy-driven integration of environmental and social criteria in an export-focused procurement process.

The recommendations that emerge from these findings - the institutionalisation of Supplier A as a primary strategic supplier, the launch of a performance improvement

initiative with Supplier F, the institutionalisation of the AHP-TOPSIS process every year, the development of procurement data systems, and the incremental strategic elevation of sustainability criteria - offer Monno Fabrics Ltd. a theoretically and practically sound, evidence-based trajectory for improving its procurement decision-making practice.

In this way, the study's findings confirm the central hypothesis of the study, that the adoption of a structured, multi-criteria supplier selection model will improve the clarity, consistency and strategic fit of procurement decisions in a Bangladesh textile manufacturing organisation, and thus contribute to improved operations and the company's long-term survival and competitiveness. The AHP-TOPSIS model presented in this thesis is not meant as a prescription, but rather as a starting point for Monno Fabrics Ltd. to develop an evidence-based, ever-improving procurement process.

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