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Optimizing risk mitigation in maritime supply chains through strategic supplier relationship management

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Abstract – Modern supply chains face escalating vulnerabilities, especially in the maritime industry. Traditional lean supply chain management lacks flexibility and risk mitigation measures, encouraging the proposal of agile-focused SCM. The success of companies is intricately tied to supplier performance, highlighting the pivotal role of procurement in risk mitigation through supplier relationship management (SRM) strategies. This emphasizes the role of procurement in risk mitigation since they manage suppliers using supplier relationship management (SRM) strategies. To properly apply SRM strategies, suppliers are segmented. The standard segmentation method is the Purchasing Portfolio Matrix (PPM). The downfall of this matrix is the focus on power relations, which misses a softer relationship side of SRM. The Supplier Potential Matrix (SPM) includes relationship dynamics but overlooks supply risk. A new matrix for segmentation is proposed, the Integrated Supplier Matrix (ISM), which combines and integrates the PPM and SPM. A case study in a maritime company assesses risks using the Best-Worst Method (BWM), revealing significant procurement risks such as product uniqueness, regulatory compliance, and external factors. The ISM then establishes relationships between supplier willingness, capabilities, risks, and profit impact. The findings emphasize the critical role of communication and trust in managing trade-offs within supplier relationship management (SRM).

Keywords: Risk mitigation; supply chain resilience; supplier relationship management; supplier segmentation; multi-criteria decision-making (MCDM); Best-Worst Method (BWM)

1. Introduction

The success of companies has been closely linked to how well their suppliers perform (Jafarian et al., 2021). This is because suppliers play an important role in how competitive companies are, as they impact multiple aspects, such as the price, quality, and delivery of products or services, affecting the supply chain as a whole (Jafarian et al., 2021). Supply chain management (SCM) is a concept that every company has to deal with, affecting both suppliers and buyers when disruptions occur. The profitability of companies facing supply chain disruptions is estimated to be 33-40% lower than that of their competition in the same industry (Tang, 2006). This is why the disruptions in supply networks can also be defined as supply chain risks, as they can affect the production and delivery of goods and services and the performance, profit impact, and competitiveness of the supply chain (Chen & Xiao, 2015). Therefore, risk mitigation in supply chains is essential in engineering and business applications.

The transformation in supply chain management, transitioning from the established principles of lean practices to the responsive nature of agile management, reflects a fundamental shift in priorities from efficiency-focused strategies to dynamic adaptability. As the conventional lean model encounters challenges in the face of modern complexities, the emergence of agile principles introduces a risk-mitigating alternative. This transformation disrupts the traditional supply chain management principle of lean practices, prompting an exploration of utilizing agile principles for risk mitigation and the creation of resilient supply chains.

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One of the most recent and impactful examples of a risk that has affected the global supply chain is the COVID-19 pandemic. The pandemic posed unprecedented challenges and uncertainties for the global supply chain, as many businesses have faced disruptions, delays, shortages, and losses due to lockdowns, travel restrictions, health risks, and demand shocks (Guan et al., 2020).

One of the major challenges that the pandemic has caused for the supply chain is material scarcity (Brown, 2022). This has suddenly made products that were once common now unique. The increased uniqueness of certain products increased competition and price volatility among buyers and suppliers, creating additional risks and uncertainties for the supply chain. Therefore, managing the supply and demand of materials is a critical issue for ensuring the sustainability and resilience of the supply chain in the post-pandemic era.

Procurement is the process of acquiring materials, equipment, and personnel for the production and delivery of goods and services (Lysons & Farrington, 2020). Procurement decisions can establish and maintain supply chain relationships by improving supplier performance, fostering innovation, and building long-term partnerships (Novack & Simco, 1991). Strong supplier relationship management is essential to reduce and mitigate operational and disruption risks. Therefore, it can be argued that supply chain success and resilience can be achieved through procurement (Roberta et al., 2014).

Since the performance of suppliers plays a crucial role in determining the outcomes of companies segmenting suppliers and formulating SRM strategies based on these segments is essential (Jafarian et al., 2021). This is because it is important to tailor approaches to the unique characteristics of each supplier group. There are multiple different ways to segment suppliers. Kraljic's Purchasing Portfolio Matrix (PPM) has become a standard among procurement departments and is used extensively to make procurement-related decisions (Rezaei & Lajimi, 2019). In recent years, the PPM has come under fire because of the narrow focus on supply and little to no focus on building relationships (Rezaei & Lajimi, 2019). Building supplier relationships is crucial as it fosters trust, communication, and collaboration (DeLemos et al., 2010).

However, while solid SRM strategies are essential for operational efficiency and competitive advantage, ineffective SRM strategies make supply chains vulnerable (O'Brien, 2014). Unfortunately, ineffective SRM strategies for risk analysis and mitigation in SCM persist as a challenge, greatly due to the infancy of using these strategies for risk management and analysis as well as a lack of a comprehensive framework (Rezaei & Ortt, 2012).

The main knowledge gap is the practical implementation of SRM strategies and the lack of an overarching supplier segmentation model. This study, therefore, introduces a novel supplier segmentation model, the Integrated Supplier Matrix (ISM), which integrates the criteria from both the PPM and the SPM. To improve the legibility of the SPM, the quadrants are named similarly to the PPM. To practically implement theoretical SRM strategies, a case study will be done and will look at the maritime industry. This is because the maritime industry is one of the most important and influential sectors in the global supply chain, accounting for around 80% of international trade (UNCTAD, 2022). However, the maritime industry is exposed to various challenges and uncertainties. Therefore, the maritime industry must make strategic investments to bolster its resilience against forthcoming crises and reduce these risks.

Here we provide the highlights of this study:

- It advances the understanding of procurement-related risks in maritime supply chains;
- It introduces a novel approach to risk prioritization using the Best-Worst Method (BWM);
- It presents an innovative application of supplier segmentation models, including the PPM and the SPM;
- It develops a comprehensive supplier segmentation model, the ISM.

2. Literature review

2.1. Lean vs. agile supply chain management

Over the years, lean supply chain management (LSCM) practices and principles have been adopted in various industries (Rossini et al., 2023). This growing interest can be attributed to the potential benefits associated with LCSM implementation, including cost savings, reduced downtime, and improved product quality (Rossini et al., 2023). The market demand for lean supply is typically characterized by predictability, whereas the demand for agile supply in the marketplace tends to be volatile (Bruce et al., 2004). Agile supply is responsive to real-time changes in demand, demonstrating market sensitivity (Bruce et al., 2004).

The agile supply chain strategy is characterized by its dynamic and continuous responsiveness to the evolving needs of customers and the competitive environment (Ahmed & Huma, 2021). This approach provides flexibility and adaptability, allowing organizations to navigate changes in the business landscape effectively. By implementing the agile supply chain strategy, organizations can respond promptly and enhance their adaptive capabilities in the face of supply chain disruptions (Ahmed & Huma, 2021). The reactive nature of the agile strategy aligns with the characteristics of a resilient supply chain, enabling quick recovery from disturbances (Ahmed & Huma, 2021). Challenging the long-standing principles of lean management that have served as the foundation for supply chain management for decades, agile management emerges as a risk-mitigating alternative.

2.2. Supplier segmentation

The relationships between buyers and suppliers in the context of SCM has always been a topic of interest. Segmenting suppliers is crucial in creating successful buyer-supplier relationships. However, one of the fundamental issues is that there are different methods for supplier segmentation, all of which use various variables and overlook some important ones (Rezaei & Ortt, 2012). The lack of an overarching framework that includes all the significant variables poses a significant knowledge gap.

The Purchasing Portfolio Matrix by Kraljic is a good starting point for understanding how risks can be posed by suppliers. Kraljic's Purchasing Portfolio Matrix is also known as the PPM and is a 2x2 matrix (Kraljic, 1983). The model categorizes supplies based on their level of complexity in the supply market compared to their importance of purchasing. Even though there is much discussion on the definitions of the two dimensions of the matrix, the following definitions will be used throughout this study:

Supply risk is the probability of an event related to incoming supply from a particular supplier or the supply market as a whole, which may lead to the purchasing company's failure to meet customer demand or pose a danger to customers' well-being and safety (Gelderman & Weele, 2003).

Profit impact is the financial value of item(s) (Gelderman & Weele, 2003).

There are movement within the PPM. Often, the movement of products within the PPM is not the buyer's strategic choice but the supplier's choice or happens due to unforeseen risks or challenges. However, sometimes, it is due to strategic choices and SRM strategies that the procurement department decides on.

Power imbalances are prevalent in the PPM. This is because of the resource dependency theory, which states that those with resources can get value from deals (Nurhayati et al., 2021). This means that inequalities in power positions can occur between buyers and suppliers. Moving to the left of the portfolio (low risk) is usually more favorable for buyers as it typically implies exerting more influence and control over the supply chain. However, moving left on the PPM can affect supplier relationships, partnerships, and overall supply chain dynamics. Therefore, balancing exerting buyer power and maintaining healthy supplier relationships is important to achieve optimal outcomes since this is the least risky position.

The Purchasing Portfolio Matrix has faced critique over the last decades. This is because, in essence, the PPM decisions are sensitive to dimensions, factors, and chosen weights (Gelderman & Weele, 2003). The terms ‘profit impact’ and ‘supply risk’ are critical, but their practical measurement remains a challenge. Consequently, there's a chance the model won't precisely capture the dimensions it's meant to assess. Another issue is that the PPM focuses on exploiting power or avoiding supplier power risk, which both lack the social aspect of building relationships with suppliers, which is contradictory (Gelderman & Weele, 2003). Business decisions are too complex to be based on just two dimensions. The PPM focuses on supplies instead of suppliers, which may lead to misalignment between buyer and seller intentions, making partnerships difficult (Gelderman & Weele, 2003).

The second matrix that will be used to segment suppliers is the SPM, the Supplier Potential Matrix, which plots suppliers' capabilities against their willingness (Rezaei & Ortt, 2012). Similarly to the Portfolio Matrix, this 2x2 matrix also has strategic directions of movement within the matrix. However, here, all directions lead to higher supplier willingness and capabilities.

A way to improve the matrix is to give each quadrant a label similar to the PPM. These labels can be compared to the bottleneck, non-critical, leverage, and strategic labels of the PPM. This will improve the readability and make referring to every quadrant less difficult. It is critical to consider that the terms selected for each quadrant cannot be used interchangeably (see Figure 1). ‘‘Reluctant’’ has been chosen for the quadrant with high capabilities and low willingness as it best represents the meaning of this quadrant. ‘‘Inept’’ has been chosen for the low capabilities and willingness quadrant. For the quadrant with high willingness and low capabilities, ‘‘overeager’’

has been chosen, and for the quadrant with high capabilities and high willingness, ‘‘reliable’’ has been chosen. Rezaei and Ortt clearly defined the supplier's capabilities and willingness to avoid confusion on the terms used, and are as follows:

Supplier's capabilities are ‘complex bundles of skills and accumulated knowledge, exercised through organizational processes that enable firms to coordinate activities and make use of their assets in different business functions that are important for a buyer’ (Rezaei & Ortt, 2012).

Supplier's willingness is ‘confidence, commitment, and motivation to engage in a (long-term) relationship with a buyer’ (Rezaei & Ortt, 2012).

There is an integrated matrix seeks to address the demand for a comprehensive framework encompassing crucial variables from both the PPM and the SPM. As was previously mentioned, this is because the PPM primarily concentrates on the power relations aspect of supply, SPM significantly emphasizes supplier-buyer relationships. The integrated matrix is a 4x4 matrix that first divides the suppliers into a quadrant of the PPM and then further divides the PPM quadrants into SPM quadrants, essentially including 4 SPMs inside of the PPM (Rezaei & Lajimi, 2019).

The downfall with the current integrated matrix is that the exact location of the suppliers in the SPM is taken into account, but the position of the suppliers on the PPM is very broad and only distinguished per quadrant, meaning the matrix makes no distinction within the PPM quadrant. For example, a supplier in the ‘leverage’ top left quadrant may vary vastly in position within the quadrant, meaning the risk and profit impact may be relatively vastly different, but this isn't considered. There is no way to make a distinction between profit impact and supply risk on the integrated matrix.

To combat this, a new version of the integrated matrix can be developed to ensure profit impact and supply risk are considered by means of a bubble chart. The bubble chart can be seen in Figure 1. Here, the x- and y-axis follow that of the SPM, which are capabilities and willingness, respectively. The bubbles each represent a supplier, and the supplier number is denoted as ‘s#' as a data label, which is placed in the center of the bubble but may be moved to be placed above or next to the bubble when there are multiple overlapping suppliers to increase visibility. The colour of the bubbles indicates supply risk, where red is a high-risk supplier, yellow is medium risk, and green is low-risk. Everything in between can be given a colour accordingly, as is depicted in the slider next to the graph. The size of the circle depicts the profit impact, where the larger the bubble, the larger the profit impact. Since the bubble chart is a 2x2 matrix and the SPM and PPM are referred to as matrices, the bubble chart will defined as the Integrated Supplier Matrix (ISM).

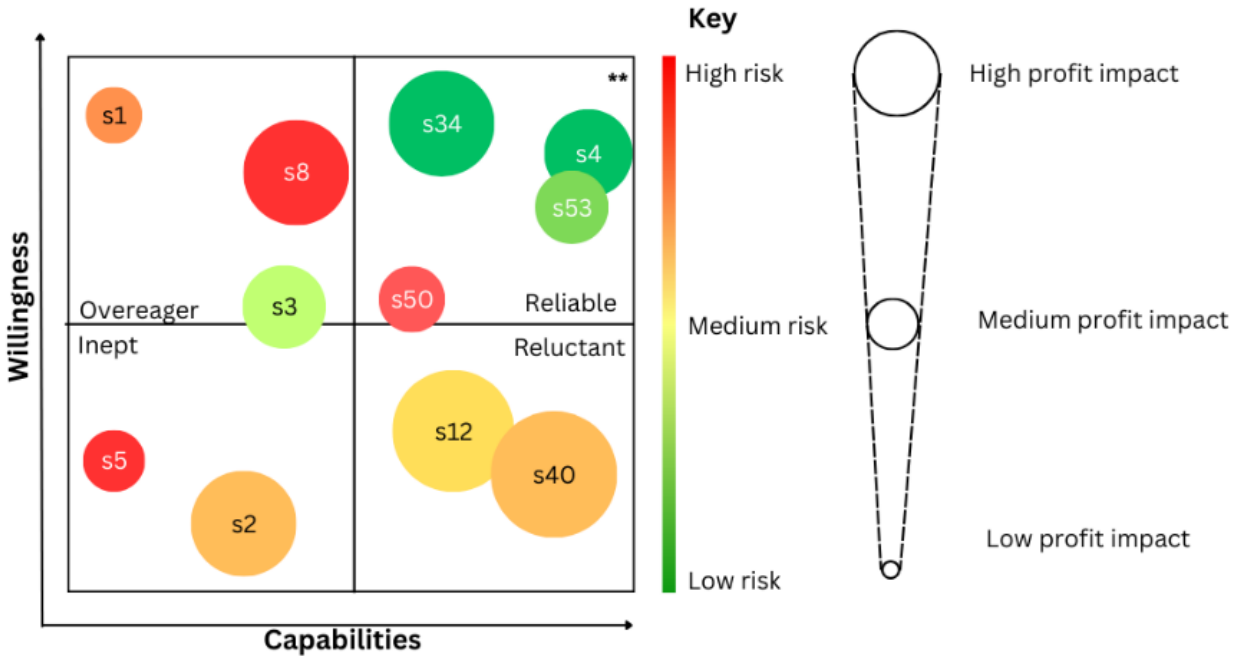

Figure 1. Integrated supplier matrix

2.3. Redefining maritime risks

Disruption risks encompass uncertainties and disturbances that disrupt regular supply chain flows; they are less frequent but more severe and often caused by external factors that are harder to predict and control. These disruptions can arise from various sources, including human-related incidents (e.g., pandemics, labour strikes, low wages, poor working conditions), technical failures (e.g., outdated facilities, slow digitization), or external factors (e.g., natural disasters, political instability, legal conflicts) (Sun et al., 2023). In contrast, operational risks that result from stakeholder interactions in routine business operations are more frequent but less severe, and internal processes usually cause them. They can include encompassing inadequate information exchange, insufficient coordination, and organizational inefficiencies (Sun et al., 2023).

Disruptive risks are often not caused by suppliers, but procurement can face challenges, or risks, with their suppliers when there are disruption risks. There may be supply interruptions due to natural disasters or labour strikes, which may lead to quality issues or increased lead times with the delivered product since the supplier may be situated in regions with political instability or may not be financially stable and, therefore, do not meet their obligations. All disruptive risks can cause a shift to the right-hand side of the PPM by changing an aspect of the supply risk criteria.

Similarly, operational risks may not be directly caused by suppliers, but their effect on suppliers' activities does affect the supply chain as a whole. Collaboration and communication, specifically in procurement, can create the problem of conflicting objectives between different functional units within a company and can hinder efficiency in the supply chain (Stadtler, 2015). Decreased efficiency in the supply chain and increased risk of disruptions can similarly cause a shift to the right-hand side of the PPM. Therefore, all risks can be defined as shift to the right-hand side of the PPM.

2.4. Supplier relationship management

Supplier relationship management is defined as a series of activities focused on establishing, nurturing, stabilizing, and terminating relationships with internal and external suppliers (Moeller et al., 2006). The primary goal of SRM is to create and enhance value within these relationships through effective supplier engagement and monitoring (Moeller et al., 2006). This process aims to reduce costs, ensure consistent and repeatable purchasing, exchange buyer expertise, and optimize collaborations with supplier (Tronnebati et al., 2022).

There are three consequent stages of SRM. The first stage is out-supplier management where buyers monitor and engage with suppliers not yet connected to the purchasing firm. The next stage is in-supplier management. When former out-supplier begin their first transaction, they become in-suppliers. This aims to establish and maintain relationships with in-suppliers to maximize value creation (Moeller et al., 2006). Finally, in-supplier dissolution management is when the chosen partnership ends, the purchasing firm can seek new potential suppliers (Moeller et al., 2006).

Formulating purchasing strategies is part of SRM, these can be formulated using the supply's or supplier's position on the PPM, where the level of strategic importance of the purchase/item is compared to other variables, such as the time horizon (Park et al., 2010). Another strategy for SRM is supplier selection. This process is needed for efficient purchasing and manufacturing (Park et al., 2010). Here, suppliers can be evaluated based on selected pre-qualification criteria. Instead of just focusing on operational metrics like price, quality, and delivery, supplier selection should be done by evaluating how well suppliers can build a long-term strategic partnership with the firm (Talluri & Narasimhan, 2004). Collaboration is the next strategy, which includes collaboration between the supplier and buyer potential (O'Brien, 2014). Collaboration is one of the biggest challenges but also desirable in the procurement supply chain. Finding and implementing collaboration strategies can enable efficiency and integration in the supply chain. Well-known collaborative approaches to SCM include Vendor Management (VM) (Park et al., 2010). Finally, the last strategy that is looked at is supplier evaluation. Supplier evaluation is the process of evaluating the value of a supplier based on their capabilities and performance (Ho et al., 2010). By implementing SRM strategies, organizations can enhance collaboration, improve supplier selection, and improve supplier performance, resulting in supply chain performance quality and consistent competitive advantage results.

Next to the specific SRM strategies, it is also important to look at the trade-offs that need to be made. The first trade-off must be made when an incumbent supplier no longer meets the buyer's expectations. One way is to handle this situation is to help the supplier improve its performance by investing resources such as time, effort,

expertise, and capital (Jafarian et al., 2021). This is known as supplier development. Some of the methods for supplier development are offering training or sharing resources (Jafarian et al., 2021). Supplier development can prove useful in improving a supplier's capabilities since there is a positive relationship between investment and improvement (Jafarian et al., 2021). The relationship follows a logarithmic function. However, putting time, money, and/or resources into the suppliers can expose buyers to potential problems, such as insufficient return on investment (Jafarian et al., 2021). Another way to handle a situation where the supplier no longer fulfills the buyer's expectations is to search for and switch to a more suitable supplier. This can happen when the investment in the supplier is too risky, or the supplier is unwilling to improve.

Another trade-off that needs consideration is the duration of time that a contract with a supplier remains in effect. Buyers must choose the best supply contracts from different options, such as long-term, and short-term contracts (Talluri & Lee, 2010). These contracts significantly impact the firm's performance and risks (Talluri & Lee, 2010). Factors such as market price uncertainty and supplier discounts should be considered when picking the right contracts. In dynamic markets with rapidly changing component costs, buyers often prefer short-term contracts to capitalize on supplier competition (for suppliers found on the left-side of the PPM) and secure the lowest costs (Merckx & Chaturvedi, 2020). Long-term contracts are often more attractive for suppliers on the right-hand side (high risk), showing a more limited number of suppliers. Long-term contracts can lead to strategic partnerships, which offer many benefits.

3. Methodology

As SRM strategies are inherently buyer-supplier-specific, a case study will be conducted within a company's procurement department. Aiming to gather and analyze data, draw robust conclusions, and formulate actual recommendations.

Initially, qualitative data collection and analysis in the form of semi-structured interviews and a literature study will be done. These interviews and literature will determine general risks in the maritime supply chain and risks experts encounter at the procurement department. To identify risks faced by the procurement department and assess the involvement of 'high-risk' suppliers, a series of interviews are conducted with 10 experts. These experts are preferred to have varying experience within the procurement department and scopes of work to contribute to the richness of the data. Using MCDM methods, specifically the Best-Worst Method (BWM), risks will be ranked during the second round of interviews.

Supplier segmentation can be done alongside the risk analysis since all the risks and all the suppliers will be segmented and analyzed. Supplier segmentation will use quantitative data, such as company data sheets on supplier's profit impact, and qualitative data, such as interviews with experts on supplier behavior and influence. Suppliers will be segmented using the PPM, SPM, and the ISM. After risks have been analyzed and prioritized and suppliers have been segmented, relationships between risks and supplier segments. Tailored SRM strategies based on this can be developed accordingly. These strategies are based on an integrated framework consisting of developing purchasing strategies, supplier selection criteria, collaboration frameworks, and supplier evaluation and management processes.

The chosen MCDM method is the Best-Worst Method (BWM), which is a pairwise comparison-based approach that systematically conducts comparisons in a structured manner. The BWM offers distinct advantages compared to other MCDM methods by checking for consistency using a consistency index. An Excel solver can be found online, which can be used to simplify and accelerate the process of implementing the BWM (Rezaei, 2015). The solver uses a linear model of the BWM (Rezaei, 2016).

The first step in the process of the BWM, and in using the solver, is defining the criteria, $\{c_1, c_2, \cdots, c_n\}$. The solver template can be used for three to nine criteria. Once the criteria are known, the best and the worst criteria must be determined. This is based on the decision-maker's preferences. The decision-maker compares the best criteria to the other criteria on a scale of one to nine. One means the criterion has equal importance to the best criteria, and a score of nine shows the best criterion is absolutely more important than the other criterion (Rezaei, 2016). The same is done for the worst criterion. The preference of the best criterion over the other criteria results in the best-to-others vector $A_B = \{a_{B1}, \dots, a_{Bn}\}$, and the preference of the criteria compared to the worst criterion results in the others-to-worst vector $A_W = \{a_{1W}, \dots, a_{nW}\}^T$. These vectors are pairwise comparison vectors. The

solver calculates optimal weights for each criterion by seeking solutions that minimize the maximum differences in $|w_B - a_{Bj}w_j|$ and $|w_j - a_{jW}w_W|$. This can be formulated mathematically as it is shown by Model 1.

$$\begin{gathered} \min max_j \{|w_B - a_{Bj}w_j|, |w_j - a_{jW}w_W|\} \\ \text{s.t.} \\ \sum_j w_j = 1 \\ w_j \geq 0, for\ all\ j. \end{gathered} \quad (1)$$

Model 1 can be equated to the minimum value of ξ^L to calculate optimal criteria weights, so that:

$$\begin{gathered} \min \xi^L \\ \text{s.t.} \\ |w_B - a_{Bj}w_j| \leq \xi^L, for\ all\ j \\ |w_j - a_{jW}w_W| \leq \xi^L, for\ all\ j \\ \sum_j w_j = 1 \\ w_j \geq 0, for\ all\ j. \end{gathered} \quad (2)$$

By solving models 2, the optimal weights, $(w_1^*, w_2^* \ldots, w_n^*)$ and the consistency index ξ^{L*} are calculated by the solver. The consistency index gauges the consistency of the pairwise comparisons. The consistency ratio is crucial for verifying the logical consistency of pairwise comparisons, ensuring reliable results. The input-based consistency ratio can be calculated using the following equations (Liang et al., 2020):

$$\begin{gathered} CR = \max_j CR_j, \\ CR_j = \frac{|a_{Bj} \times a_{jW} - a_{BW}|}{a_{BW} \times a_{BW} - a_{BW}}, a_{Bw} > 1, \\ CR_j = 0, \qquad a_{BW} = 1. \end{gathered} \quad (3)$$

There are thresholds for different combinations of n and a_{BW} using input-based consistency measurement. These threshold values for the consistency ratio allow the solver to make recommendations on whether the pairwise comparison consistency level is acceptable or not by comparing the input-based consistency ratio to the associated threshold. The pairwise comparison consistency level is acceptable if the CR is not greater than the associated threshold (See Liang et al., 2020, for the thresholds).

4. Case study results

At the selected company, the procurement manager deliberately uses the strategic PPM, explicitly utilizing the adapted version with directional streams. The company utilizes several other tools for supplier management, including SRM decision-making. Additionally, they employ supplier evaluation forms and pre-qualification questionnaires, which are useful starting points for this study.

4.1. Qualitative data

The supplier evaluation forms are filled out by an expert either from the procurement or the technical department and are a way of determining a supplier's capabilities and willingness. The latest version of the form

included 55 suppliers. Supplier names have been removed to protect the privacy and confidentiality of the suppliers and entities involved.

Using literature, the criteria from the evaluation forms will be determined to be either supplier willingness or supplier capabilities. There is a distinct preference per criterion on whether they fit as willingness or capabilities. Once this is done, it is determined that from the twelve criteria, eight are capabilities, and four are willingness. Table 1 shows the division of supplier criteria based on literature.

Table 1. Supplier evaluation criteria as willingness or capability

Criteria	Willingness or Capability
Safety performance	Capability
Environmental performance	Capability
Completion of work/services	Capability
Performance of work/services	Capability
Subcontractor's subcontractors	Capability
Project team	Capability
Final (as-built) documentation	Capability
Administrative management/ invoicing	Capability
Business ethics	Willingness
Corporate social responsibility	Willingness
Variations to work/services (attitude)	Willingness
Information/communication	Willingness

Initially, a deliberate selection of ten employees with different roles, sub-departments and experience was chosen. After seven interviews, it was clear that the interviews had reached a point where the perceived risks and examples of supply chain disruptions had become saturated, meaning that no extra information was learned. This saturation was a positive sign, indicating that a comprehensive understanding of the subject matter had been gained. The recorded interviews were then transcribed and coded using Delve.

4.2. Quantitative analysis

The information from the interviews was divided into these categories: perceived risks, types of supply chain disruptions and their examples (risks experienced), consequences of supply chain disruptions and their examples, suppliers involved in the disruption, risk prioritization and criteria, risk mitigation strategies, and improvements. After coding the data using Delve, the data was analyzed further.

The analysis of the frequency of mentions of experienced risks shows that the uniqueness of the product, rules and regulations, external factors, product lifecycle, and communication and coordination are the most frequent. However, product lifecycle was mentioned by only one expert in different examples, which casts doubt on its importance. The other risks that ranked highly seemed to have directly affected the majority of the interviewees. Therefore, even though product lifecycle is an important risk, it is evaluated or taken into account as one of the most important risks. Communication is also affected by many other factors. This causes communication to be excluded from the ranking of important risks as it seems to be caused by other risk factors. Therefore, it can be concluded that the most important risks are the uniqueness of the product, rules and regulations, and external factors.

The BWM was used to determine the importance, or weights, of the three risks. Since interview saturation was reached after seven interviews with experts, the remaining experts were asked to conduct the pairwise comparisons using the BWM . Table 2 shows the results of BWM. As can be seen, the uniqueness of the product is the most important risk at 49%, rules and regulations come second with 39%, and external factors come third with 19%. The consistency ratios (CR) are also shown. They are all relatively close to zero, and below their associated thresholds, showing high levels of consistency.

Table 1. Weighted risk importance

	Uniqueness of product	Rules and regulations	External factors	CR
Expert 1	0.58	0.11	0.32	0.05
Expert 2	0.44	0.39	0.17	0.16
Expert 3	0.45	0.45	0.1	0.12
Aggregated	0.49	0.31	0.19	

The interviews also revealed seven suppliers frequently involved in supply chain disruptions. These suppliers, labeled 56, 57, 58, 59, 60, 61, and 62, reached saturation when the interviewees mentioned no new names. They will be assessed and categorized along with the 55 suppliers with the completed supplier evaluation forms.

The weighted risks from the BWM have prioritized the procurement-related risks faced. In theory, using these weighted risks, the suppliers can be given weighted scores and, based on this, receive a score for their overall supply risk, but this was not easy to do in practice. Two experts tried to determine the supply risk for the 62 suppliers (55 suppliers from the supplier evaluation forms plus the seven suppliers from the risk interviews) but found that the product uniqueness, or the number of available suppliers, was the simplest indicator of supply risk. This was because other factors, such as rules and regulations and external factors, affected the number of available suppliers, so they were already considered. The supply risk was then measured on a scale from 0 to 100 based on the number of available suppliers and filled in per supplier by experts.

To determine where in the PPM, as well as the ISM, the supplier will be plotted, profit impact needed to be determined. This has been determined by summing the total monetary value of purchase orders over the last five years per each given supplier. Five years was chosen since this is the length of time that the supplier evaluation template has been. The profit impact is shown on the matrices using a random logarithmic scale that helps to conceal the supplier identity.

4.3. The purchasing portfolio matrix

Using the values of profit impact and supply risk for each supplier, the PPM can be plotted. This can be seen in Figure 2. The PPM is a bubble chart to better visualize the effect of profit impact on supplier position, as each bubble's diameter corresponds to the percentage of the total profit impact contributed by the segmented suppliers. The orange bubbles are the seven seemingly high-risk suppliers mentioned in the interviews. \

Suppliers can be found in all segments of the PPM; this means that choosing these suppliers can lead to varied outcomes that will be interesting to compare when plotted on the SPM and the ISM. This also shows that subcontractors really come in all types of economic value and supply risk. For the PPM, the SPM, and the ISM, high-risk suppliers will be defined as those with a supply risk of above 50%. Eight suppliers meet this criterion, which is about 13% of all the suppliers.

However, these high-risk suppliers account for about 39% of the total profit impact and have a higher average profit impact compared to low-risk suppliers. This shows that there is a positive relationship between supply risk and profit impact. The PPM does not show this relationship clearly, probably because of the random logarithmic scale used for the y-axis.

More interesting to note is the location of the suppliers mentioned in the interviews on risk analysis. It shows that only three are found in the strategic quadrant, one in the bottleneck quadrant, two in the non-critical quadrant, and one in the leverage quadrant. It is interesting to look into why suppliers that were mentioned in the interviews with repeated risk occurrences do not automatically make a supplier high risk. The supply risk of each supplier is not determined by the number of available suppliers alone but by various factors that were identified in the interviews and the literature study. However, the number of available suppliers was the only criterion used to assign supply risk to each supplier, which explains why there are repeated risk occurrences with suppliers that do not automatically have a high supply risk. Only supplier 56 adheres perfectly to the narrow definition of supply risk, which is based on the number of available suppliers. There are no other risk factors that affect this supplier other than the uniqueness of the product they offer, so there is no change in the PPM for this supplier.

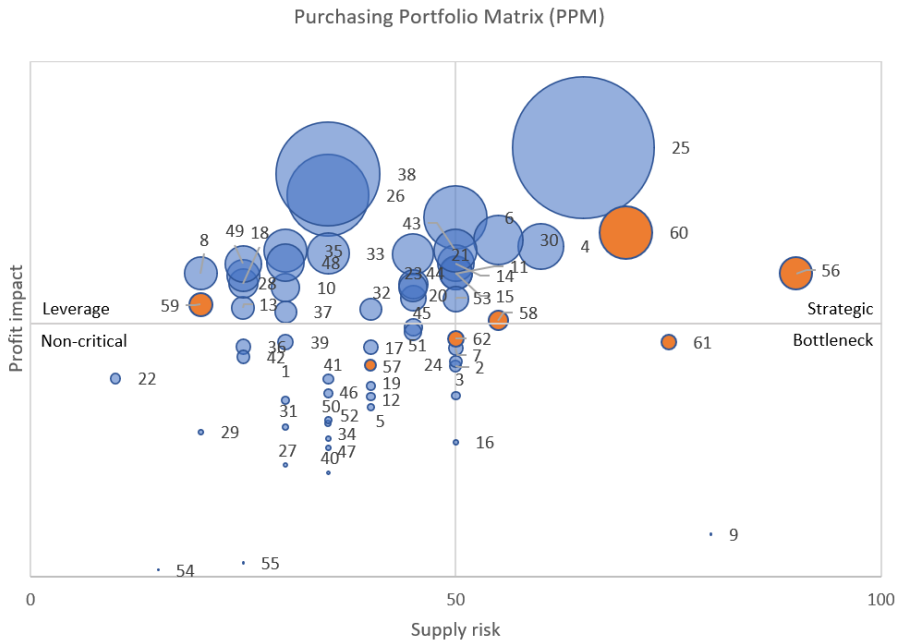

Figure 2. Purchasing portfolio matrix

4.4. Supplier potential matrix

Experts give criteria from the evaluation form a score between 0 and 3, where 0 is poor/ no information, 1 is adequate, 2 is good, and 3 is excellent. The company has assigned its own weights to the criteria. However, for this study new criteria weights are determined using the BWM. The willingness and capabilities of a supplier are subjective criteria. This makes the reproducibility of this research more difficult and is therefore going to be determined based on the existing criteria. The suppliers are also given one of the four approval ratings: approved and preferred, approved with controls, not preferred, and not approved and blacklisted. It is interesting to compare the approval rating.

Two experts were briefed on the BWM and conducted pairwise comparisons using the BWM to evaluate supplier criteria twice: once for willingness criteria and once for capabilities criteria. Table 3 displays the aggregated results in the BWM column. The comparison of results is shown in Table 3. A notable difference between the BWM and the original criteria weights is the higher emphasis on "performance of work and services" in the capabilities criteria. This may indicate a misalignment with procurement priorities, as the supplier evaluation form was not designed by procurement. Surprisingly, "variations to work/service" or attitude holds a weight of 51%, signifying its significant importance as perceived by both experts.

Table 2. BWM supplier criteria compared to previous weights

Criteria		Original (Normalized)	BWM	Difference
Safety performance	Capability	12.50%	13.84%	1.34%
Environmental performance	Capability	6.25%	2.92%	-3.33%
Completion of work/services	Capability	25.00%	16.72%	-8.28%
Performance of work/services	Capability	25.00%	26.95%	1.95%
Subcontractor's subcontractors	Capability	6.25%	9.71%	3.46%
Project team	Capability	6%	9.71%	3.46%
Final (as-built) documentation	Capability	6.25%	8.99%	2.74%
Administrative management/ invoicing	Capability	6.25%	11.15%	4.90%
Business ethics	Willingness	20.00%	14.26%	-5.74%
Corporate social responsibility	Willingness	20.00%	6.52%	-13.48%
Variations to work/services (attitude)	Willingness	40.00%	50.99%	10.99%
Information/communication	Willingness	20.00%	28.23%	8.23%

To calculate the suppliers' willingness and capabilities scores, the normalized BWM weight per criterion is multiplied by the score the supplier has received (between 0 and 3) for that criterion. The total supplier willingness can be calculated by adding the willingness criteria and the same can be done for the supplier's total capabilities. To calculate the scores for the suppliers from the risk interviews without supplier evaluation forms, the evaluation form was completed by two experts each, one from the technical department and one from the procurement department.

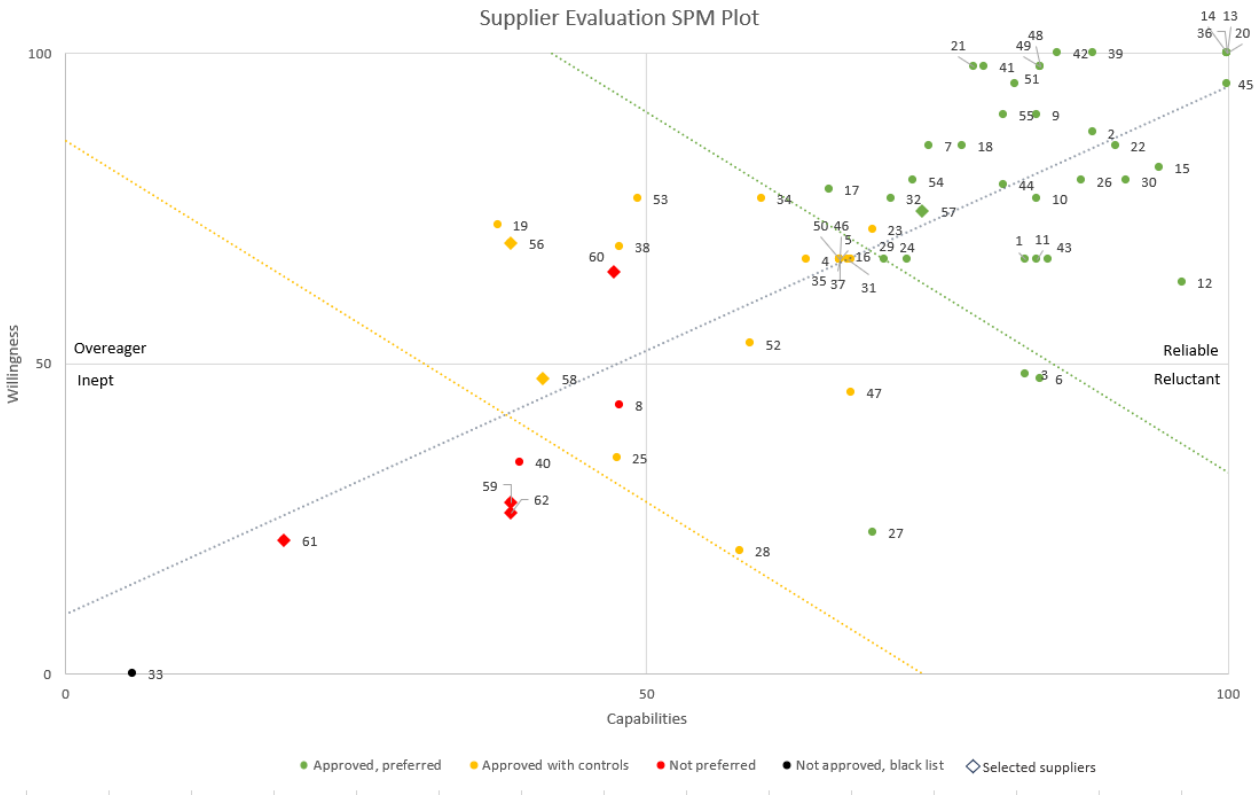

Figure 3. Supplier potential matrix

Figure 3 shows the SPM. The diamonds on the SPM represent the suppliers that were identified as high risk in the risk analysis interviews. The legend shows the approval ratings. The SPM shows that there is a positive correlation between the willingness and capabilities of the suppliers. This means that the more willing a supplier is, the more capable they are, and vice versa. As expected, the approved and preferred suppliers have the highest scores of willingness and capabilities. The approved with controls suppliers have relatively high scores but lower than the approved and preferred ones. The not preferred suppliers have low scores of both willingness and capabilities. The blacklisted supplier has the lowest scores, indicating that it is completely inept. The approval ratings form three distinct clusters on the SPM. These clusters can be separated by finding the perpendicular trendline and changing the c value of the equation y = mx + c to find the midpoint between two clusters.

4.5. The integrated supplier matrix

The ISM is graphed using data on profit impact, supply risk, supplier willingness, and capabilities, and can be seen in Figure 4. The matrix shows a correlation between supply risk and supplier attributes, indicating that higher-risk suppliers tend to exhibit lower willingness and capabilities. Where low-risk suppliers are suppliers with supply risk of less than 50% and high-risk suppliers have a supply risk of greater than 50%. Table 4 shows the aggregated results for both groups in terms of profit impact, willingness, and capabilities. Overall, high-risk suppliers have a greater profit impact but lower willingness and capabilities on average, while low-risk suppliers show the opposite trend.

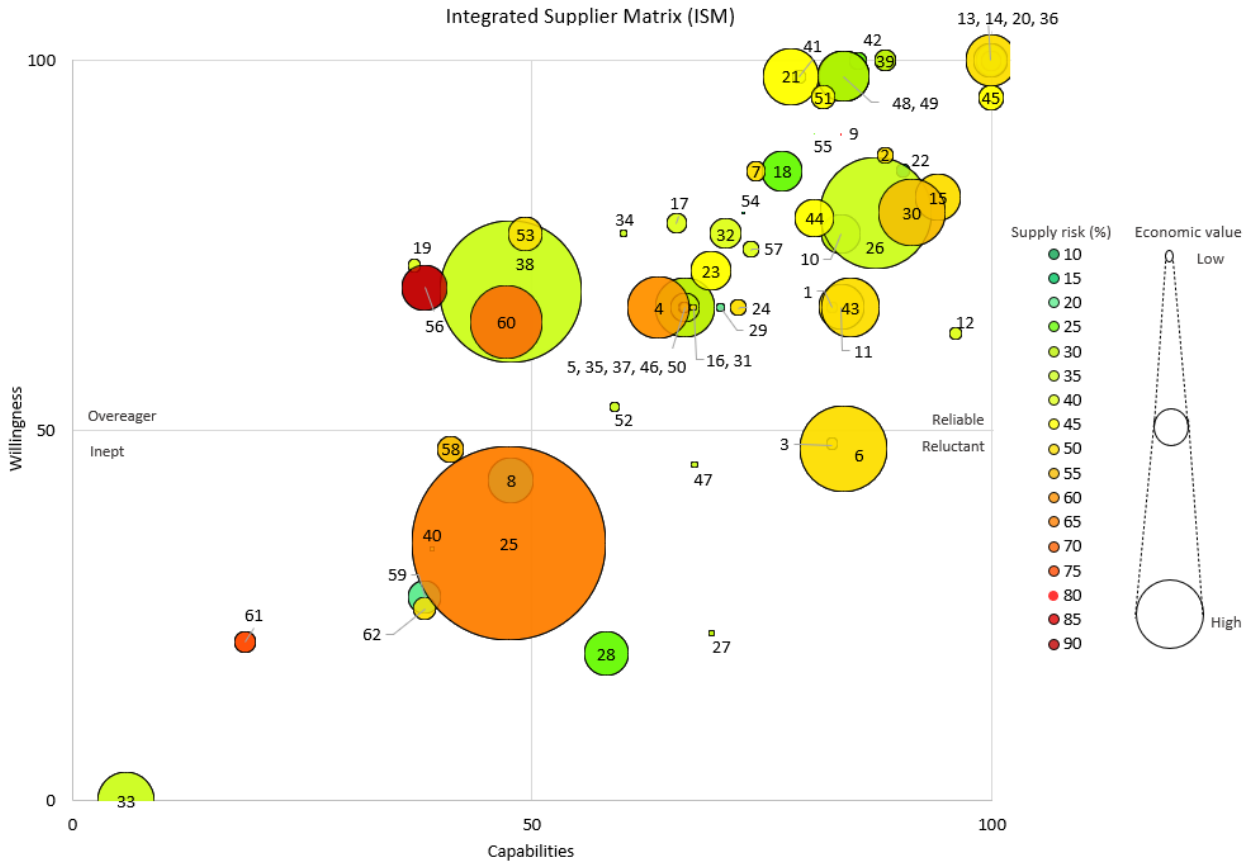

Figure 4. Integrated supplier matrix

Table 3. Average results for high risk and low-risk suppliers

Type	# of suppliers	% of total	Capabilities	Willingness	Profit impact
Low risk (≤ 50%)	54	87.10%	72.8	71.04	1.14%
High risk (>50%)	8	12.90%	53.94	59.24	4.83%

To determine relationships between specific risks and supplier segments, the suppliers from the risk interviews can be looked at further on the ISM. Although the data on types of risks and involved suppliers is limited, some patterns can be observed. The suppliers that faced or still face risks due to rules and regulations (57, 60) are found in the overeager and the reliable quadrant, both showing high willingness. The suppliers with risks due to technical failures (61, 62) are in the inept segment, with both suppliers showing low willingness and capabilities. Similarly, the supplier with threats due to capacity utilization issues (59) is found in the inept quadrant, showing low willingness and capabilities. The supplier with raw material issues (58) is also found in the inept segment with low capabilities and willingness. Finally, the supplier with a risk due to the uniqueness of the product (56) is in the overeager segment, which shows that they have high willingness but low capabilities.

5. Supplier relationship management

Power is regarded as a fundamental element of supplier relationship management (Nurhayati et al., 2021). Nurhayati (2021) characterized inter-organizational power as the possession and control of essential assets that enable an entity to acquire and increase wealth through ongoing influence over customers, competitors, and

suppliers (Nurhayati et al., 2021). Resource dependence theory explains why those with resources can get more value from deals (Nurhayati et al., 2021). This theory suggests that companies should examine all the resources they can use as power over others in their supply chains (Nurhayati et al., 2021). The goal is to control how power dynamics evolve in relationships, leading to better business results. By being able to recognize and acknowledging this inequality can serve as the initial phase in proactively addressing collaboration risks for both parties in the future.

The PPM guides procurement decisions and supplier relationship management decisions based on exploiting or avoiding supplier power risk, which often ignores the social aspect of building relationships with suppliers. This can be useful when power relations and power imbalance can be used to the company's advantage by working with low-risk suppliers on the left side of the PPM (low risk), but this does not always work in the company's favor since approximately 13% of suppliers are high-risk suppliers, which means the suppliers have more bargaining power here. This inequality is why working with non-preforming incumbent low-risk suppliers is not recommended, especially with suppliers that find themselves in this situation and still show low willingness and capabilities. In this situation, the buyer has more power since there is usually an abundance of low-risk alternatives to the incumbent supplier. The buyer will likely find suppliers more willing to work with them and excel in different capabilities criteria, such as price or quality.

5.1. Trade-offs in supplier relationship management strategies

Comparing the literature review to the risks encountered at the given company, it is clear that trade-offs must be made. These trade-offs include choosing between short and long-term supplier contracts, investing in or switching non-performing suppliers, choosing between single or multiple sourcing, and finally, choosing sole sourcing or manufacturing in-house.

When examining Supplier 61, the case study company could have considered pre-emptive inventory management to reduce risks. Given the company's large warehouse, maintaining a strategic stock of critical items could act as a buffer during supplier interruptions and temporarily reduce supply chain disruptions. This can be achieved by reviewing inventory levels and refilling them proactively to mitigate potential risks. However, there are risks associated with high inventory levels, such as changing demand patterns and product obsolescence. To find a balance in this, the company could focus on building strong relationships with their supplier, securing long-term contracts, and implementing better lifecycle management practices to avoid excessive inventory and remain flexible in adapting to changing circumstances.

Next to inventory storage, another trade-off is the duration of supplier contracts. While some argue against extended relationships due to evolving business trends, factors like reduced search costs through the Internet and the growing focus on mitigating supply chain risks challenge the idea of minimizing supplier numbers in favor of long-term commitments (Talluri & Lee, 2010). Short-term and long-term contracts present advantages and disadvantages concerning performance criteria such as price and risk. It is suggested that buyers tend to favor long-term contracts with a small supply base, where suppliers have limited alternatives and may position themselves favorably on the right-hand side of the PPM (Merckx & Chaturvedi, 2020). On the other hand, larger supply bases prompt buyers to leverage intense competition and prefer short-term contracts to seek lower-cost suppliers in each period (Merckx & Chaturvedi, 2020).

Long-term contracts can foster strategic partnerships, offering benefits like reduced total cost of ownership, especially for suppliers on the left-hand side of the PPM, who face significant competition and often offer lower costs to secure long-term contracts (Merckx & Chaturvedi, 2020). The case study company consistently prefers long-term contracts when possible since they are able to end contracts if expectations aren't met, proving profitable in all scenarios. This approach makes long-term contracts favourable for the case study company.

The procurement manager at the case study company deliberately transitions suppliers from the leverage to the strategic quadrant in Kraljic's matrix by fostering long-term relationships through contractual agreements, consequently increasing supply risk. While partnerships with suppliers can foster trust and reliability, they can also engender dependency and vulnerability during supply chain disruptions. Diversifying sources by engaging two or more suppliers for the same product is preferable, yet not always feasible due to product uniqueness, scarcity, or urgent and complex situations. Supplier 59 and Supplier 61 were intentionally chosen as single sources despite the availability of multiple supplier options, leading to increased supply risk by heightening dependence. Although both had terminable long-term contracts, the decision to single-source resulted in challenges.

Buyers consider power dynamics within the supply base when deciding between single or multiple sourcing strategies. Although single sourcing can enhance learning effects and reduce costs, it may strengthen the supplier's bargaining position, posing risks (Heese, 2015). Therefore, for risk mitigation in SRM, dual-sourcing emerges as the preferable option. This ensures an alternative source is available, even if one supplier dominates the majority of the business, such as a 95%-5% split between suppliers A and B.

Another trade-off is whether to use a sole source or manufacture it in-house. Larger firms facing high competition and integrated technology levels can achieve profitability through R&D efforts (Talluri & Lee, 2010). Engaging in numerous in-house R&D projects enables the development and manufacture of unique products (Merckx & Chaturvedi, 2020). However, profitability in R&D aligns with heightened competition, prompting quicker resource allocation for R&D activities to expand market share. Moreover, competitive pressure drives companies to enhance operational efficiency and reduce costs through R&D-driven improvements in processes and technologies.

Products or services facing high competition usually fall on the left-hand side of the PPM, indicating little need for internal production or R&D investment (Merckx & Chaturvedi, 2020). Instead, the focus shifts to potentially internally producing unique products, although investing in highly specialized products beyond core competencies may not be effective. Effective communication and trust with suppliers become crucial to mitigating supply chain disruptions (Talluri & Lee, 2010). Regarding Supplier 56, despite their distinctive products, in-house production poses challenges such as specialized expertise and investments in the form of time and money. Although Supplier 56's uniqueness is a supply chain risk, they are still deemed reliable and preferred suppliers, highlighting the complexities of SRM (Merckx & Chaturvedi, 2020).

The final trade-off looked at in this study is the trade-off between investing in and switching non-preforming incumbent suppliers. The literature review establishes a positive logarithmic relationship between investment and improvement. As investment in suppliers increases, improvement may initially progress slowly but accelerate with higher investment (Jafarian et al., 2021) . Higher investment in resources, technology, or infrastructure can enhance production efficiency, lower unit costs, and ultimately increase profits over time, corroborating the correlation between investment and improvement.

Investing in suppliers to enhance performance is worthwhile, particularly for unique products with high demand, despite the potential risks involved (Deng, 2023). For supplier 56, which is the sole supplier of a unique product, it could be worth the investment since the supplier finds itself in the overeager quadrant of the ISM. Assuming that the results of the ISM are generalizable, and most suppliers that are high risk due to the uniqueness of their product can be found in the overeager quadrant with supplier 56, then it can be assumed that they have high willingness and lower capabilities, making them more likely to be willing to enhance their capabilities with investment.

On the other hand, suppliers 61 and 62 have low capabilities and willingness and face risks due to technical failures, and supplier 59 suffers from the same problem and is at risk due to their capacity utilization issues. These issues are likely specific to each company, not the whole market. Although the risks are assumed to be common for each supplier segment, they are not faced by all suppliers in the same market. In this scenario, there is little incentive to persist with these suppliers. The game theory further supports the idea of switching or renegotiating with non-performing incumbent suppliers when the buyer has a power advantage (Chatterjee & Samuelson, 2003). If there are multiple other options available, the party with the highest bargaining power, which in the case of suppliers on the left side of the PPM are the buyers, should consider or switch to the most attractive party, or they can negotiate a better deal with the incumbent supplier (Chatterjee & Samuelson, 2003).

5.2 Risk mitigation through communication and building trust

Effective communication is crucial in addressing supply chain risks, as highlighted in Section 4 where it emerged as one of the most frequently perceived risk factors. Communication and building trust also seem to be key features or solutions to most trade-offs in SRM. This is because effective communication is crucial for addressing supply chain risks, empowering buyers to proactively manage disruptions. Trust within buyer-supplier relationships significantly influences performance and reduces supplier costs (Chumpitaz, 2019). Open communication channels and established trust inform buyers promptly about supply chain issues, reducing the need for multiple sourcing (DeLemos et al., 2010). Suppliers demonstrating willingness to communicate and collaborate are valuable investments, outweighing capability concerns. Initiatives like regular communication

channels, joint planning sessions, and mutual performance goals strengthen communication and trust, forming the foundation of effective SRM strategies.

Improving trust and communication is particularly valuable for critical or strategic suppliers, enhancing supply chain resilience. Targeted approaches mitigate risks, especially with sole suppliers, facilitating collaborative problem-solving. Continuous communication and feedback contribute to ongoing performance improvement, reducing the likelihood of risks. Building trust and communication with key suppliers creates a proactive framework for addressing and mitigating potential risks (Chumpitaz, 2019).

6. Discussion

The discussion will encompass areas of research that warrant further exploration, identifying gaps in existing knowledge, and suggesting avenues for future investigations. A critical analysis of the current literature, and using logical reasoning, aims to highlight the unresolved aspects and the possible reasons why they remain unclear or unresolved.

The initial discussion examines the generalizability of subcontractors compared to standard suppliers. The findings indicate that subcontractors demonstrate a wide range of supply risk and profit impact, ranging from 10% to 90%. To validate the generalizability of these results, a comparison was made between subcontractors and a randomly selected sample of 366 suppliers. The analysis revealed that subcontractors exhibited an average profit impact 11.74% higher than the sampled suppliers, highlighting their specialized expertise and ability to provide customized, high-value customer services. This increased average profit impact observed in subcontractors can be attributed to several factors. The most notable is that subcontractors specialize in niche areas not typically within the core competencies of standard suppliers, allowing them to charge higher rates for tailored solutions. However, due to the large variety in profit impact, supply risk, willingness and capabilities, it seems reasonable to consider subcontractors as representative of standard suppliers.

The next point of discussion is the perception-based nature of this study. The importance of supplier criticality and the definition of risk in supplier segmentation require careful consideration. While this paper focuses on suppliers, internal communication issues and uncoordinated behaviors within the buying company can influence risk perception. Internal factors can shape the perception of risks associated with lead times, demonstrating the impact of internal dynamics on supplier criticality. For example, Supplier 59 was single-sourced despite alternative options, leading to forecasting challenges, capacity problems, and delivery issues. This raises questions about whether the high-risk label reflects the supplier's true profile or results from internal choices and mistakes within the company. Dual or multiple sourcing strategies could have provided alternative suppliers. Biases, such as recency bias and confirmation bias, affect risk perception in supplier selection (Azzopardi, 2021). Practices like regular supplier evaluation forms, improved communication, and data-driven decision-making can mitigate biases and enable informed decisions based on current information rather than historical biases. This research relied solely on expert opinions from the procurement department due to the absence of quantitative data and the research topic's nature. Challenges in interviews included limited expert availability and potential bias in selection. However, reaching saturation quickly suggested consensus among experts. Supply risk in the PPM was calculated based only on the number of available suppliers, per experts' preference, despite other influencing factors like rules, regulations, and geopolitical factors. The PPM results showed suppliers could move quadrants based on factors beyond availability, contradicting the assumption that it solely determines supply risk. This discrepancy stems from Kraljic's vague definition of supply risk, allowing interpretation variations. While supply risk measurement was consistent, the dynamic nature of suppliers in the matrix, influenced by various risks, was not accounted for.

The next discussion point is why high-risk suppliers have lower willingness and capabilities but higher profit impact. Long-term contracts offer mutual stability, especially for low-risk suppliers facing high competition. These suppliers are incentivized to maintain contracts by demonstrating higher capabilities and willingness. The concept of economies of scale is crucial, favoring larger markets with cost efficiencies. Left-side PPM suppliers benefit from cheaper manufacturing costs due to multiple investors, influencing their lower profit impact. Perfect competition in these markets drives prices based on supply and demand forces. Conversely, suppliers on the right side of the PPM exhibit lower average willingness and capabilities, leveraging their power dynamics. Dependency on unique products or niche markets limits their scalability and, consequently, their capabilities. This lack of scale

may lead to higher profit impacts as they cannot offer lower prices. However, they can leverage their uniqueness to charge higher prices to dependent buyers, typically large profit-making firms.

7. Conclusion

This research project has extensively explored the development of strategic supplier relationship management (SRM) strategies to mitigate supply chain risks, with a specific focus on the maritime industry. Utilizing the Best-Worst Method (BWM), the study effectively ranks and assesses supply chain risks, setting a solid foundation for proactive SRM strategies aimed at enhancing performance and resilience. The study challenges the traditional lean management approaches, advocating for a more relationship-based, agile, and communicative SRM approach that is better suited for addressing contemporary operational and disruption risks.

The case study presented informs strategic SRM recommendations, emphasizing the importance of communication and trust-building to facilitate early risk identification and collaborative problem-solving. Employing the Integrated Supplier Matrix (ISM), the research highlights the necessity of segmenting and prioritizing suppliers based on their risk, profit impact, capabilities, and willingness to engage. This approach ensures targeted risk mitigation and effective supplier development. It is emphasized that continuous performance monitoring and maintaining flexibility are crucial for implementing quick corrective actions, particularly with high-risk suppliers who require tailored SRM strategies due to their significant profit impact and lower capabilities and willingness. Moreover, dual-sourcing strategies are recommended to ensure resilience for low-risk suppliers.

By integrating SRM and risk mitigation strategies into ERP implementations or collaborative initiatives, the study illustrates how procurement supply chain resilience can be enhanced, fostering enduring partnerships. The research underscores that incorporating risk mitigation through robust SRM practices is indispensable for a resilient and adaptable supply chain, applicable across varying scales of companies. Through strategic relationship management, proactive risk mitigation, and continuous adaptation, supply chains can effectively navigate the complexities of the modern business environment, thereby securing long-term stability and growth.

This research faced several limitations, primarily due to its heavy reliance on qualitative data from expert interviews, which were both time-consuming and challenging due to experts' busy schedules during a major procurement project. The need to repeatedly approach experts for additional information exacerbated the issue, particularly in completing extensive supplier evaluation forms, which proved impractical. Additionally, an inherent bias assumed the procurement department as the primary entity interacting with suppliers, overlooking the technical department's significant involvement.

Furthermore, a notable gap in the literature on the generalizability of risk assessment across different supplier segments necessitated reliance on logical reasoning rather than empirical evidence. This underscores the importance of further research to validate these findings, potentially through comparative studies between regular suppliers and subcontractors, or by expanding the scope to include additional case studies from similar maritime companies.

Recommendations for future research include exploring alternative multi-criteria decision-making methods beyond the Best Worst Method (BWM) and employing AI-driven data systems to enhance risk assessments. Additionally, training programs focused on risk management and addressing perception biases can help foster a culture of data-driven decision-making and continuous improvement in supplier evaluations.

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