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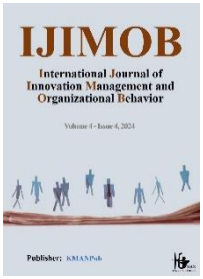

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Analysis and Ranking of Factors Affecting Resilient Supply Chain with a Combined Approach

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A B S T R A C T

Objective: Today, there is increasing competition among various organizations, and one of the competitive tools is supply chain management. Existing pressures and disruptions for companies have led to working under uncertain conditions. Therefore, the supply chain must be made resilient. Such a chain is of great importance in the oil industry, which is one of the country's most essential activities. Accordingly, this study seeks to identify and prioritize the factors affecting a resilient supply chain in the oil industry.

Methodology: This research was conducted in one of the active companies in the oil industry. Initially, semi-structured interviews were conducted with 10 experts from the company, who were purposefully selected, and analyzed using the thematic analysis technique.

Findings: This analysis identified 13 factors. In the next step, using the Best-Worst Method (BWM), these factors were ranked, with financial factors, flexibility, the use of experienced managers, the use of backup suppliers, and foresight being ranked first to fifth, respectively.

Conclusion: Overall, it is recommended to focus on these underlying factors as the foundation of supply chain resilience.

Keywords: *Resilient Supply Chain, Oil Industry, Thematic Analysis, Best-Worst Method.*

1 Introduction

Countries exhibit different reactions when faced with economic shocks that may alter the trajectory of national growth and development. These reactions and the measures taken to confront such shocks depend on the economic robustness of a country, the type and intensity of its weaknesses, and economic turbulence (Azevedo et al., 2010). Several Southeast Asian countries, including Indonesia, South Korea, Malaysia, Thailand, and the Philippines, were severely impacted by the 1997 Asian financial crisis, experiencing a sharp decline in their Gross Domestic Product (GDP). However, these same countries, by adopting appropriate policies and learning from previous crises, managed to mitigate the effects of the 2007 financial crisis on their economies, returning to their growth paths nine months earlier than many European and American countries (de Mesquita Souza Saraiva et al., 2022; Dubey et

al., 2019; Kauppi et al., 2016; Mani et al., 2016; Sadeghi Moghadam et al., 2018; Sadeghi Moghadam et al., 2019).

Currently, the global perspective on natural, social, and economic risks has shifted from focusing on reducing vulnerability to increasing resilience. Consequently, the application of the concept of resilient communities and the creation and strengthening of their pathways have become more prevalent (Mani et al., 2016). Various individuals and schools of thought, based on their views and approaches, have focused on the concept of resilience in the economic field and organized their studies accordingly (Kazmane et al., 2014). A system is resilient when it can absorb temporary or permanent shocks and adapt to rapidly changing conditions without losing stability (Melnyk, 2014; Sawik, 2013).

The existing pressures and disruptions for companies have resulted in operating under conditions of uncertainty. Thus, the supply chain must be made resilient, and the characteristics and performance indicators of resilience must be identified and implemented in the supply chain (Brandon-Jones et al., 2014). Resilient companies are less exposed to disruptions and demonstrate greater ability to cope with disruptions in the supply chain. To create a resilient supply chain, it is first necessary to have a proper understanding of the structure, objectives, strategies, relationships among supply chain components, and existing risks and hazards in the supply chain. Despite the country's heavy reliance on oil revenues and the critical importance of uninterrupted production and development projects, and despite the oil industry's long-standing issue of sanctions, the implementation of the resilient supply chain concept has been very limited, with only a few limited experiences and no systematic approach in this regard (Carvalho & Cruz-Machado, 2011; Chowdhury & Quaddus, 2015; Erol et al., 2010; Jafarnejad et al., 2015; Melnyk, 2014).

Furthermore, the increasing diversity of processes, the continuous introduction of new technologies, the specialization of work activities in this field, the expansion of offshore construction, the construction of floating spheres, the establishment of pipelines, the drilling of oil and gas wells, the construction and operation of new plants, the continuous influx of human resources with varying levels of education and expertise, globalization, and extensive international interactions have made the management of the oil industry more specialized and complex. It is no longer possible to manage this industry under conditions of uncertainty using traditional and unscientific methods.

A supply chain disruption is an event that disrupts the flow of goods or services and service delivery within the supply chain (Bakshi & Kleindorfer, 2009). Today, one of the most critical issues in the supply chain is supply chain resilience. In recent years, the emergence of new technologies and significant transformations in global markets have made attention to the supply chain more necessary than ever. Various organizations, to create and maintain their competitive position, must inevitably use supply chain management. Some reasons for the necessity of focusing on the supply chain include the rapid advancement of technology, the inclination towards outsourcing, the emphasis on customer satisfaction, the focus on process management, and the integration of operations (Jafarnejad et al., 2015).

On the other hand, one of the major concerns in the offshore and drilling operations sector, as the executor and operator of major oil and gas field projects, is the timely completion of these projects according to the schedule. Timely provision of raw materials and equipment, reliable and fast transportation of structures and pipelines, and ensuring safe and sufficient storage space to meet client requirements and satisfaction are of great importance in this industry. Disruption in the supply chain of this industry is an event that disrupts the execution and operation of projects and service delivery in the supply chain.

Based on the above, the main question of this research is: What factors play a role in the resilience of the supply chain in the oil industry, and how are they prioritized? To answer this question, initially, interviews were conducted and analyzed using thematic analysis to identify the criteria. Then, using the Best-Worst Method (BWM), which is one of the multi-criteria decision-making methods, the factors were prioritized.

2 Methods and Materials

The present research is applied in terms of purpose and qualitative-quantitative in terms of data nature. In terms of data collection method, it is field research conducted through semi-structured interviews, and thematic analysis was used for data analysis. It should be noted that for prioritization, a pairwise comparison matrix questionnaire was distributed among experts, and the factors examined in these matrices were the findings of the thematic analysis method. Thematic analysis is a method for identifying, analyzing, and reporting patterns (themes) within data. This method organizes and describes data in detail (Abedi Jafari et al., 2011).

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The thematic analysis process begins when the analyst considers potential patterns and themes that have inherent appeal. This analysis involves continuous back-and-forth movement between the entire dataset and the coded summaries, and the analysis of the emerging data. Writing the analysis starts from the first stage. Generally, there is no unique way to start a study on thematic analysis.

The six phases of thematic analysis based on the Braun and Clarke (2006) method are explained below. The thematic analysis is a recursive process where there is movement back and forth between the phases. Additionally, thematic analysis is a process that occurs over time (Braun & Clarke, 2006).

Phase 1: Familiarization with the Data: To become deeply familiar with the content and scope of the data, the researcher must immerse themselves in the data, usually by "repeated reading" and actively reading the data (i.e., searching for meanings and patterns).

Phase 2: Generating Initial Codes: This phase starts when the researcher has read and familiarized themselves with the data. It involves the creation of initial codes from the data. Codes represent a feature of the data that appears interesting to the analyst. Coded data are different from themes, which are units of analysis.

Phase 3: Searching for Themes: This phase involves sorting the different codes into potential themes and collating all the relevant coded data extracts within the identified themes. Essentially, the researcher begins to analyze the codes and consider how they can combine to form an overarching theme.

Phase 4: Reviewing Themes: This phase starts when the researcher has devised a set of candidate themes and involves reviewing and refining these themes. It includes two levels of review. The first level involves reviewing at the level of the coded data extracts. In the second level, the validity of themes in relation to the dataset is considered. If the thematic map works well, the next phase can proceed. If not, the researcher must rework the codes until a satisfactory thematic map is achieved. By the end of this phase, the researcher should have a clear idea of the different themes, how they fit together, and the overall story they tell about the data.

Phase 5: Defining and Naming Themes: This phase begins when there is a satisfactory thematic map. The researcher defines and further refines the themes for analysis, identifying the essence of what each theme is about. Through definition and refinement, it becomes clear what aspect of the data each theme captures.

Phase 6: Producing the Report: This phase starts when the researcher has a fully worked-out set of themes. It involves the final analysis and writing of the report.

In this study, based on the four criteria below, the statistical sample (research experts) was selected purposefully and non-randomly from the Marine Facilities Company:

At least 10 years of experience in various supply and support sections.

Possessing at least a bachelor's degree.

Familiarity with supply chain and resilience topics.

Having at least one experience in management or supervision.

Based on these criteria, the sample size was over 10 individuals.

3 Findings and Results

In accordance with the aforementioned steps of thematic analysis, researchers coded each interview immediately after conducting it and then proceeded to the next interview. Based on the interviews and coding, the final table categorizing the themes and their frequency was obtained as shown in Table 1.

Table 1

Categorization of Themes

Row	Theme	Frequency
1	Legal Issues	6
2	Teamwork	6
3	Environmental Conservation	5
4	Contingency Reserves	4
5	Experienced Management	9
6	Flexibility	9
7	Information Technology Usage	4
8	Training	5
9	Financial	10

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10	Training	4
11	Market Knowledge	8
12	Backup Suppliers	9
13	Foresight	8

Items such as supply chain strategies, transparency, risk-taking, innovation, transparency, and accountability, which had a frequency of less than three, were not included in the prioritization.

It is noteworthy that to accurately and appropriately name the main and sub-themes derived from the interviews, the literature and research background were consulted.

The Best-Worst Method (BWM) is one of the novel multi-criteria decision-making techniques categorized under multi-attribute decision-making. It was introduced by Jafar Rezaei in 2015 in an article. In this method, the best and worst criteria are specified by the decision-maker, and pairwise comparisons are made between each of these two criteria (best and worst) and the other criteria. Then, a max-min problem is formulated and solved to determine the weights of the various criteria. Moreover, a formula for calculating the inconsistency rate to verify the validity of the comparisons is considered. Notable features of this method compared to other multi-criteria decision-making methods include:

- Requires fewer comparison data.
- Leads to more robust comparisons, meaning it provides more reliable answers.

In this technique, we deal with pairwise comparisons of criteria. When using the pairwise comparison a_{ij}, the decision-maker expresses the direction and strength of the performance of i relative to j. In most cases, the decision-maker does not have an issue with expressing the direction, whereas expressing the strength of the performance is a challenging task that often leads to inconsistencies.

Step 1: Determine the Set of Research Criteria

In the first step, the research problem must be identified, and then the factors influencing the research objective are extracted. Finally, these must be confirmed by the research experts. This step was conducted in this study using the thematic analysis method.

Step 2: Compare the Best Criterion with Other Criteria (BO) and Other Criteria with the Worst Criterion (OW)

In this step, the most important and least important criteria among all criteria are identified as the best and worst, respectively. Then, pairwise comparisons between the best criterion and the other criteria, and between the other criteria and the worst criterion, are formed into two matrices and answered using a 1 to 9 scale.

Step 3: Create the Linear Programming Model

In this step, using the following relationship, the linear optimization model of the BWM is formed.

To avoid lengthening the article and its calculations, based on the opinion of two out of ten experts in the research, two linear programming models along with their corresponding solutions are presented. Using Lingo software, the values of w were calculated, and the results are shown in Table 2.

Table 2

Weight Values of Variables Based on the Opinions of the First and Second Experts

Variable	Symbol	Value According to Model of Second Expert	Value According to Model of First Expert
Legal Issues	W1	0.061	0.073
Teamwork	W2	0.053	0.054
Environmental Conservation	W3	0.044	0.032
Contingency Reserves	W4	0.018	0.005
Experienced Management	W5	0.128	0.143
Flexibility	W6	0.142	0.146
Information Technology Usage	W7	0.011	0.009
Training	W8	0.068	0.007
Financial	W9	0.161	0.142
Training	W10	0.009	0.013
Market Knowledge	W11	0.081	0.117
Backup Suppliers	W12	0.128	0.123
Foresight	W13	0.096	0.136

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In the next stage, to unify the opinions of the two experts, the geometric mean was used, and the prioritization was obtained as shown in Table 3.

Table 3

Final Weights and Convergence with Thematic Analysis

Variable	Weights Using Geometric Mean	Frequency in Thematic Analysis	Prioritization
Legal Issues	0.067	6	7
Teamwork	0.053	6	8
Environmental Conservation	0.038	5	9
Contingency Reserves	0.009	4	13
Experienced Management	0.135	9	3
Flexibility	0.144	9	2
Information Technology Usage	0.010	4	12
Training	0.022	5	10
Financial	0.151	10	1
Training	0.011	4	11
Market Knowledge	0.097	8	6
Backup Suppliers	0.125	9	4
Foresight	0.114	8	5

The prioritization of variables is based on their weights, and it is noteworthy that this prioritization converges with the frequency of variables in the thematic analysis.

4 Discussion and Conclusion

Today, many companies are exposed to supply chain disruptions. The consequences of supply chain disruptions range from short-term to long-term losses. Unwanted and unforeseen disruptions can lead to supply chain failures. Although researchers have examined procedures to reduce vulnerability, it is not possible to completely eliminate the vulnerability of supply chains. The increasing vulnerability of supply chains and exposure to disruptions necessitate new management methods to minimize them. To maintain and improve supply chain performance after a disruption, supply chains must be resilient. As mentioned earlier, this issue is particularly crucial in the country's oil industry.

Therefore, this study aims to identify and prioritize the factors influencing a resilient supply chain in the oil industry. For this purpose, interviews were used to identify the influential factors. Through purposive sampling of managers from the Marine Facilities Company, one of the main active companies in the oil sector, and conducting semi-structured interviews with ten individuals, multiple factors were identified. For initial screening, factors mentioned four times or more by experts were considered. In the next step, two experts were asked to complete the pairwise comparison questionnaire related to the Best-Worst Method. Based on the method's steps and solving the linear programming model using Lingo software, the factors were prioritized for each expert, and then the final prioritization was conducted using the geometric mean technique.

Flexibility is a crucial factor in resilience, as noted by Chopra and Sodhi (2014) and Melnyk et al. (2014) in their studies (Chopra & Sodhi, 2014). Financial and investment factors also ranked first, as Melnyk et al. (2014) highlighted in the context of supply chain resilience (Melnyk, 2014). Chowdhury et al. (2015) mentioned market, demand, management, and information technology factors. The innovation and distinction of this research from other studies on supply chain resilience lie in the three factors of foresight, training, and teamwork, which have not been addressed in similar studies (Chowdhury & Quaddus, 2015).

Based on the top five prioritized factors, the following recommendations are provided:

Considering the financial factor as the top priority, ensure adequate funding to prevent potential disruptions in the supply chain.

For the second factor, flexibility in supply, consider alternative routes, clearance, and various contingency options.

For the third factor, employ experienced managers who have participated in various projects and can share their knowledge and experience.

For the fourth factor, use backup suppliers in critical situations where replacements are possible.

Lastly, plan meticulously with foresight, taking into account potential future disruptions.

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Overall, it is recommended to focus on the five factors of financial stability, flexibility, experienced management, backup suppliers, and foresight as the foundational elements of supply chain resilience. Other researchers are encouraged to conduct similar studies in other organizations in the oil sector and compare their results with this research. For such studies, other methods that structure the issue, such as Interpretive Structural Modeling (ISM), should be used.

Authors' Contributions

All authors have contributed significantly to the research process and the development of the manuscript.

Declaration

In order to correct and improve the academic writing of our paper, we have used the language model ChatGPT.

Transparency Statement

Data are available for research purposes upon reasonable request to the corresponding author.

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Declaration of Interest

The authors report no conflict of interest.

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Ethical Considerations

In this research, ethical standards including obtaining informed consent, ensuring privacy and confidentiality were observed.

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