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Rough Process for Selecting the Most Effective Functions of Supply Chain Flexibility Based on Competitive Value Integration Propositions: A Case Study of Petrochemical Industry

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ABSTRACT

In a complex and ever-changing environment, competitive values play a crucial role in shaping the supply chain strategies of companies operating in an industry, such as the petrochemical industry. The greater the integration of a company's competitive values against other competitors, the more influential the supply chain flexibility is due to a better understanding of market drivers. The purpose of this study is to evaluate the rough analysis process to select the most effective functions of supply chain flexibility based on the propositions of the integration of competitive values in the petrochemical industry. The methodology of this research is hybrid, and the Delphi and Rough collection were used to perform meta-synthesis analysis. The target population in the qualitative sector was similar research and academic experts in industrial management. However, the target population was a small number of 23 managers with experience in petrochemical companies, which is acceptable from the statistical population due to the need to analyze the Rough process. In this study, based on the combined analysis of selected researches, five propositions of competitive value integration and five components of supply chain flexibility were determined, which entered the Rough collection analysis phase according to the confirmation of theoretical adequacy based on the Delphi analysis. The results in this section identify the most compelling propositions for integrating the competitive values of companies operating in the petrochemical industry: demand-based management propositions (P2), creating innovative values (P3), and reducing operating time (P5), which affects the flexibility of the supply chain and causes the flexibility of financing as the most effective

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component of the flexibility functions in the supply chain in the petrochemical industry.

1. Introduction

In today's competitive world, other traditional supply chain management practices that were less integrated with their procedures do not work because environmental change, social development, technological development, and increasing cultural contradictions have led to far-reaching changes in this area (Shafiee et al., 2013). The need to make the right decision and choose the correct option from among the many options in various fields such as choosing the best manufacturer, the best distributor, the best area to attract customers, and the best business partners in building integrations are essential issues in deciding to create integrated values in supply chain management. These decisions range from minor issues to large and significant issues, and in many of these cases, if the decision is incorrect, considerable costs are imposed on companies operating in a competitive environment (Ghazizadeh et al., 2015). As a result, organizations can no longer achieve a competitive advantage and increase their market share as a separate product or service unit and need a planned and principled partnership with their suppliers and customers. As a result, organizations must partner in integrated supply chains rather than as isolated islands (Cigdem and Anand, 2017). Value integrity in the supply chain is defined as the degree to which the manufacturer engages strategically with its supply chain partners and jointly manages the internal and external processes of the organization (Khanuja and Jain, 2019). Because supply chain value integration is a promising yet complex tool that is still considered a weapon to reach maturity in a competitive environment to enhance the dimensions of business development (Ataseven et al., 2020), the need to pay attention to it can help companies as a competitive advantage to create a level of resilience to be flexible in the face of an ever-changing environment. Therefore, many researchers have created different paradigms based on sustainability and agility during the past years, and based on supply chain flexibility, created a level of value integration for a more significant competitive advantage. It is important to note that the supply chain needs to be flexible because its operation has always been subject to various uncertainties, such as customer demand and supplier capacity under turbulent economic conditions (Irfan et al., 2019). In other words, with increasing structural complexity at the level of markets and production processes, customer needs must be met in the shortest possible time by increasing the level of flexibility of the supply chain cycle because the flexibility of the supply chain reflects the capabilities and capabilities of the system to respond quickly and appropriately to internal and external changes in the system. From the perspective of the importance of conducting this research, it is essential to note that supply chain flexibility can also promote value integration in the supply chain by reducing cycle time and re-processing, while it can help increase the level of competitive effectiveness. This study seeks to analyze value integration based on supply chain flexibility in petrochemical companies. In this regard, the importance of this research should be stated. Although, in less than a decade, many researchers such as Cagliano et al. (2006), Kim and Cavusgil (2009), Gimenez et al. (2012), and Delic et al. (2019) have provided components and indicators of supply chain flexibility, less research has examined the level of integrity of supply chain values. The lack of a coherent model and theories related to this field caused the researchers in the direction of today's unstable economy to provide a coherent model of linking theories with applied facts at the level of petrochemical companies by theoretically screening the components and indicators based on a Rough set,. Therefore, this research seeks to develop a level of value integration based on supply chain flexibility by citing the articles of the law of the Fifth Development Plan and focusing on Article 156 of this law to develop the petrochemical industry in order to expand the integrity of the value chain and Article 12 of the Law on development of competitiveness of petrochemical companies to improve the country's financial system (Office of Energy, Industry and Mining Studies, 2015) and by reducing production costs and competitive agility in regional and international markets under a resilient economy.

2. Literature review

2.1. Sustainable supply chain management

The concept of sustainable supply chain management has been extensively studied in the last two decades. Development efforts over the 1960s have focused primarily on the economic aspects of sustainable development (Hutchins and Sutherland, 2008). After the 1960s, the non-economic aspects of development

activities were also considered. Moreover, in the 1980s, the concept of sustainable development was introduced: extensive development of this concept, various dimensions of supply chain sustainability literature in the form of social dimensions, what is in terms of economic dimensions, what is in the form of cultural dimensions, what is discussed in the form of environmental dimensions, which often included common goals. In an Elkington's (2011) classification of research literature, sustainability is divided into three main pillars of economic, environmental, and social divisions. It is noteworthy that prior to 2000, there was no explicit, coherent, independent definition of sustainable supply chain management. However, the definitions have become more purposeful and broader in scope since 2001. In one definition, sustainable supply chain management can be considered an integration of corporate sustainability into supply chain management in which the main dimensions of corporate sustainability are associated with the characteristics of supply chain management (Ahi and Searcy, 2013). On the other hand, Stivastava (2007) defines sustainable supply chain management from an environmental perspective and states integrating environmental thinking with green supply chain management, including product design, material sourcing and selection, production processes, final product delivery to end customers, and the management of products after their useful life. As mentioned, the process of defining sustainable chain management definitions revolves around a three-dimensional cycle (3BL), including economics, environment, and society, and other exciting aspects of the proposed definitions include external stakeholder pressures and the idea of management. A sustainable supply chain goes beyond the traditional business concept but is also related to economic performance (Adesanya et al., 2020). From an operational point of view, sustainable supply chain management is considered a subset of internal and external processes, emphasizing the role of cooperation between supply chain partners. Strategic integrity, transparency, and the achievement of social goals and environmental and economic goals of the organization are defined through the systematic coordination of key inter-organizational processes to improve the long-term economic performance of companies and their supply chain (Baliga et al., 2019).

3. Supply chain flexibility

Flexibility has become a common term among managers, researchers, and supply chain consultants. Nevertheless, what is the meaning and concept of flexibility? Flexibility refers to the ability of a system to survive, adapt, and grow in the face of change and uncertainty (Soni et al., 2014). In the definition of others, flexibility is the ability of the supply chain to return to the initial state (before disorder) or move to a new situation that is more desirable than before (Fakoor Saghih, 2015). Regarding supply chain flexibility, we can only refer to conceptual studies, which primarily include a literature review and definitions or principled guidelines based only on compelling examples (Singe et al., 2019). Lummus et al. (2003) supply chain flexibility can be defined as the speed of the supply chain in meeting customer demand and the degree of adaptation of production volume in response to various market changes. Vickery et al. (1999) present supply chain flexibility in the following form (Figure 1).

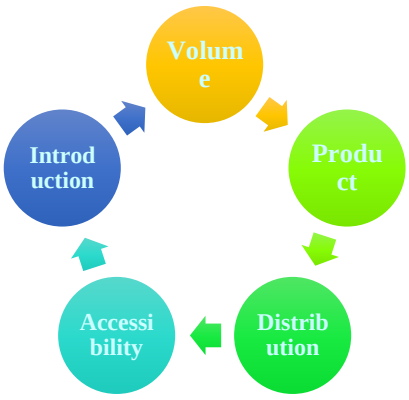

Figure 1. Five-dimensional model of supply chain flexibility (Source: Vickery et al., 1999)

Vickery et al. (1999) believed that from the above five dimensions, there is an interrelationship between the first two components, namely volume flexibility and product flexibility, leading to supply chain flexibility in manufacturing systems and flexibility in distribution and access to market process approaches. Furthermore, the flexibility to introduce a new product is also linked to research and development (R & D) teams to develop flexibility of the supply chain (Irfan et al., 2019). Sawhney (2006) noted two important aspects of supply chain flexibility: process flexibility and distribution flexibility. Swafford et al. (2006) also expressed supply chain flexibility into three dimensions: sourcing flexibility, construction flexibility, and distribution flexibility.

4. Supply chain value integration

Supply chain integration is the degree to which the manufacturer collaborates with supply chain partners and manages processes within and outside the organization as a group to achieve competitive advantage (Flynn et al., 2010). Stevens (1989) first considered value integration to include the following three dimensions (see Figure 2).

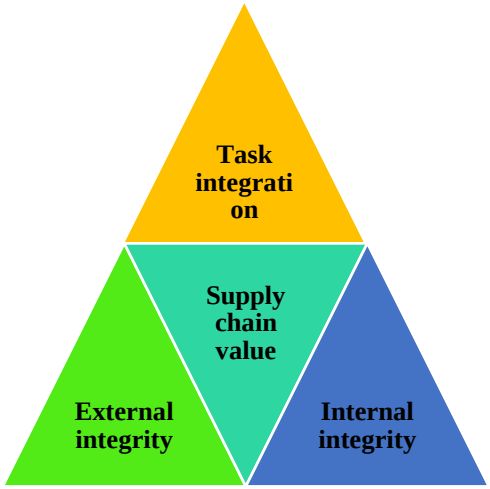

Figure 2. A three-dimensional approach to supply chain value integration (Source: Stevens, 1989)

As can be seen, integration is defined according to Stevens (1989) in three levels of task integration, internal integration, and external integration, which includes integration with suppliers and customers; then researchers identify and introduce other dimensions of integration.

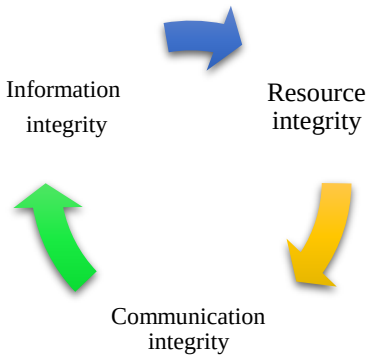

Figure 3. Supply chain value integration according to Lee and Hang (2004).

The researchers introduced supply chain value integration in three dimensions: information integration, coordination and resource sharing, and organizational connectivity and relationships with partners, but emphasized communication integrity given the ever-changing environment. Thus, the internal integration, supplier integration, and customer integration were introduced as three dimensions of the integrated supply chain (Wong et al., 2011; Venpouke et al., 2013). According to various research, integration is classified into two dimensions of internal and external integration (Mirhabibi et al., 2018), and external integration includes two dimensions of customer integration and integration with suppliers. Wong et al. (2011) defined internal integration as the process of interaction and collaboration in a group that brings other groups together to create a cohesive organization, and there are practical tools to make connections between all tasks. Supplier integration refers to the process of interaction and collaboration between an organization and its suppliers to ensure adequate supply flow. Integration with suppliers increases capacity and improves performance indicators such as delivery, quality, and cost. Customer integration refers to the cooperation and strategic coordination of a central organization with its customers. Cigdem and Anand (2017) believed that this dimension of integration helps understand customer and market expectations and opportunities and leads to a more accurate and faster response to customer needs and requirements by matching supply with demand. Based on the presented theoretical foundations, the research questions are:

1. What are the components of flexibility in the supply chain?
2. What are the integration propositions of competitive values?
3. What are the most effective components of supply chain flexibility based on value integration propositions in petrochemical companies?

5. Literature review

Piprani et al. (2021) conducted a study entitled "Prioritizing economic sustainability based on sustainable supply chain: analytical hierarchy process (AHP) in the textile industry". This research used a two-step method. In the first stage, the existing literature was reviewed, and based on this, expert panel consultation was conducted to identify flexibility factors in the different stages of the supply chain. In the second stage, the analytic hierarchy process method was used to rank the elasticity factors required in the Pakistani textile industry. The results show that creating an integrated supply chain ranking requires focusing on economic change because economic sustainability by adopting appropriate and environmentally friendly policies can contribute to supply chain dynamics. The results also show that companies should focus on the stage of readiness for financing because this stage is classified as the most crucial stage.

Salleh et al. (2020) conducted a study entitled "Development of large supply chain paradigm for experimental study in the Egyptian shipping port system". Four sustainable supply chains, namely green, lean, resilient, and agile, were analyzed as paradigmatic dimensions of the large supply chain based on theoretical screening. This research, which was a combination, was first developed with the participation of 15 research experts to develop a significant supply chain paradigm. Then, based on the participation of 117 managers in different parts of the Egyptian shipping port system, an attempt was made to explain the dimensions of the model in the target community. The results showed that the development of the significant supply chain paradigm helps reduce costs and speed up business interactions in shipping. The most important and influential supply chain is the sustainable supply chain, which can be considered the main driver in developing interactions between companies. Nath and Agrawal (2020) conducted a study entitled "Analysis of agile supply chain and lean supply chain in corporate social sustainability". The purpose of this study was to investigate the impact of the above two supply chains on the position of companies in the social environment in the form of social responsibilities, maintaining interaction and communication with customers, and environmental protection. The statistical population of the study was 311 managers of manufacturing companies in India. Partial least squares (PLS) analysis was used to analyze and fit the model, and exploratory analysis and factor loads were used to reinforce the researcher-made questionnaires. The results showed that the use and expansion of the two chains of the study, namely agile supply chain and lean supply chain, will strengthen the level of the social status of the company because flexibility in providing resources and improving the level of knowledge in competitive interactions in a pure way promotes the social status of the company. Izadyar et al. (2020) conducted a study entitled "Sustainability performance evaluation model of large supply chain management methods in the automotive supply chain using system dynamics". First, by reviewing the literature and interviewing industry experts, extensive

supply chain management methods were identified and prioritized using a fuzzy network analysis process, and an integrated approach of extensive supply chain management methods was presented. Finally, the system dynamics approach has been used to evaluate the dynamics of effective supply chain management practices and their impact on sustainable supply chain performance. Findings show that scenarios of improvement in the implementation of total quality management, timely production execution, and flexible transportation make the supply chain more stable. The results obtained from implementing these scenarios indicate an improvement in supply chain stability, and the results show that lean strategy is essential in achieving stability in the supply chain. The proposed model helps industry managers and decision-makers identify the results obtained from implementing large supply chain management practices and improve the practices that affect supply chain sustainability by taking measures. Ayoubi Mehrizi and Shahbazi (2020) conducted a study entitled "Assessment of large supply chain maturity in Saipa Yadak Company using fuzzy inference system (FIS)". The sampling method in this study was judgmental, and finally, the number of experts in the sample designed to confirm the rules was seven people. In the present study, a fuzzy expert system was designed to calculate the level of maturity of the large supply chain in organizations. The main dimensions of the system were lean, agile, resilient, and green supply chain. The designed system was tested and validated, and the results showed the validity and reliability of its performance. This system was also used to calculate the level of maturity of the large supply chain in Saipa Yadak Company.

6. Methodology

Given three fundamental results, the purpose and type of data in any research methodology should be stated. As a result, this research is considered developmental research because the concepts related to the analysis of supply chain flexibility based on value integration are not theoretically coherent. This research seeks to develop the theoretical basis of value chain flexibility, which is considered a development from this perspective. Further, based on the purpose, this research is among the descriptive researches to explain the phenomenon in the field of the supply chain. Finally, in terms of logic, data collection is inductive–deductive because in the qualitative part, it first examines the theoretical foundations related to the dimensions of supply chain flexibility and the integration of competitive values by relying on the inductive approach and then deduces them based on deductive action.

Furthermore, propositions are identified in the target community. In this combined research, in the qualitative part, meta-synthesis was used. The meta-synthesis includes steps to arrive at components and propositions that range from recognizing the root cause of the problem in the form of a research question to providing a specific model based on identifying components and propositions from previous research through the participation of panel members. Then, based on the Delphi analysis, in order to determine the theoretical adequacy according to the two criteria of average and coefficient of agreement, an attempt is made to analyze the components and propositions back and forth between experts. Finally, in the quantitative part, the most effective dimension of supply chain flexibility is selected by the analysis of the total value according to the value integration propositions.

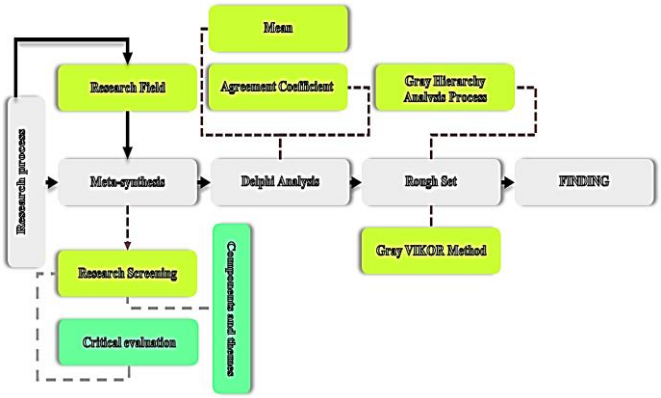

Figure 4. The diagram of the research methodology.

7. Statistical population of the research

The statistical population in the qualitative sector includes 15 specialists and experts in the field of industrial management at the university level, who have a specialized and scientific approach in this regard by conducting scientific research in a similar field. These individuals were selected through the homogeneous sampling method because the goal was for the people who participated in this section to have a theoretical view of the research topic. Moreover, based on meta-synthesis, this part of the research used sites such as University Jihad (SID) in Iran, Iran Magazine Database (MAGIRAN) Iran, Islamic Computer Science Research Center (NOORSOFR) Iran, International Sciencedirect, Emeraldinsight, and OnlineLierary to determine components (supply chain flexibility) and research indicators (value integrity). In the second phase, to perform the Rough Set, 23 managers with experience in petrochemical companies, as the panel members, were asked. After evaluating the identified components and propositions of the quality section and confirming them, they should respond to the developed matrix questionnaires. In fact, since this method is based on the analysis of complex systems at certain levels and should be based on specific criteria, such as experience or expertise by participants, the cross-matrix questionnaire should take up to 30 people due to the lack of a large number of incomprehensible answers,. Researchers such as Zhang et al. (2016), Shyng et al. (2007), and Pawlak (2005) predicted the optimal sample size selection in the range of 15 to 25 people based the selection of the sample population in the available sampling method and according to the filters following the nature of the research.

8. Research validity

The content validity ratio (CVR) was used to validate the constructed questionnaires, based on which 10 panel members were asked to fulfill three "important" criteria and to determine "useful but not appropriate" and "unnecessary" claims. Each researcher selected one of the above three choices to affirm the study's validity. In the end, all the propositions determined to be above the set standard (CVR) were approved.

9. Procedures for the Rough set theory

Pawlak (1982) introduced the Rough sets as a valuable mathematical instrument in uncertainty conditions (Pawlak, 1982). After the Rough set theory, Zhai et al. (2002) proposed the Rough numbers. A Rough number usually includes "lower limit", "upper limit", and "Rough boundary interval", which depends only on the original data. Hence, there is no need for supplementary data, and this can gain a better understanding of the experts' intended concepts and improve the decision-making objectivity (Pawlak, 1982).

Suppose that "U" is a reference set including all members, and "Y" is an arbitrary member of U and R sets belonging to "t class", R= {G1, G2,…, Gt} which covers all members of U. If these classes are in order G1 < G2 < … < Gt, then $\forall Y \in U. G_q \in R. 1 \le q \le t$.

The lower approximation ($\underline{\mathrm{Apr}}(G_q)$), the upper approximation ($\overline{\mathrm{Apr}}(G_q)$), and the boundary area ($\mathrm{Bnd}(G_q)$) belonging to class Gq are defined as:

$$\underline{\mathrm{Apr}}(G_q) = \cup\{Y \in U | R(Y) \le G_q\} \quad (1)$$

$$\overline{\mathrm{Apr}}(G_q) = \cup\{Y \in U | R(Y) \ge G_q\} \quad (2)$$

$$\begin{aligned}\mathrm{Bnd}(G_q) &= \cup\{Y \in U | R(Y) \ne G_q\} \\ &= \{Y \in U | R(Y) > G_q\} \\ &\cup \{Y \in U | R(Y) < G_q\}\end{aligned} \quad (3)$$

Then, Gq can be presented using a Rough number (RN), Gq, in its corresponding lower and upper limits: (Equations (4)–(6)).

$$\underline{\mathrm{Lim}}(G_q) = \frac{1}{M_L}\sum R(y) | Y \in \underline{\mathrm{Apr}}(G_q) \quad (4)$$

$$\overline{\mathrm{Lim}}(G_q) = \frac{1}{M_U}\sum R(y) | Y \in \overline{\mathrm{Apr}}(G_q) \quad (5)$$

$$\mathrm{RN}(G_q) = \left[\underline{\mathrm{Lim}}(G_q).\overline{\mathrm{Lim}}(G_q)\right] \quad (6)$$

where MU and ML are the values of members $\underline{\mathrm{Apr}}(G_q)$ and $\overline{\mathrm{Apr}}(G_q)$, respectively.

It is clear that the lower and upper limits determine the mean value of the elements related to upper and lower approximations, respectively, and their difference is defined as "Rough boundary interval".

$$\mathrm{IRBnd}(G_q) = \overline{\mathrm{Lim}}(G_q) - \overline{\mathrm{Lim}}(G_q) \quad (7)$$

The Rough boundary interval expresses the ambiguity of "Gq" so that its large value indicates high ambiguity, while its smaller value denotes high accuracy. Thus, the subjective data can be expressed by the Rough numbers.

10. Gray hierarchy analysis process

The gray hierarchy analysis process is one of the most famous and commonly used multiple decision making, which can measure the level of preferences' consistency and consider the tangible and intangible criteria. The gray relational analysis method is used to select the best choice based on the number of criteria. This method, like the TOPSIS and VIKOR techniques, starts with a decision matrix. However, in addition to the distinction between the positive and negative criteria, it distinguishes between the most desirable values. The gray hierarchy analysis process was used in this research because the experts' judgments were subjective and ambiguous. In the following, the gray hierarchy analysis process is presented.

Step 1. Determine the goals, criteria, and choices of the research and form the hierarchy structure;

Step 2. Prepare the pairwise comparison questionnaire and collect the experts' opinions;

Step 3. Using the concept of Rough theory to change the experts' preferences to interval numbers and form the interval pairwise comparison matrix like the below equation:

$$M = \begin{bmatrix} [1.1] & [x_{12}^L . x_{12}^U] & \dots & [x_{1m}^L x_{1m}^U] \\ [x_{21}^L x_{21}^U] & [1.1] & \dots & [x_{2m}^L x_{2m}^U] \\ & & \vdots & \\ [x_{m1}^L x_{2m}^U] & [\dots & \dots & [1.1] \end{bmatrix} \quad (8)$$

where x_{ij}^L is the lower limit, and x_{ij}^U represents the upper limit.

Before computing interval numbers, the inconsistency rate of the pairwise comparison questionnaires should be measured, and if this rate is acceptable (below 0.1), we can compute the interval numbers.

Step 4. Calculate the weight of each of the research's criteria using Equations (9) and (10);

$$w_i = \left[\sqrt[m]{\prod_{j=1}^{m} x_{ij}^L} . \sqrt[m]{\prod_{j=1}^{m} x_{ij}^U} \right] \quad (9)$$

$$w_i' = w_i / \max(w_i^u) \quad (10)$$

where w_i' is a normalized form. Finally, the weight of the research criteria is obtained (Zhu et al., 2018).

11. Gray VIKOR method

Step 1: In the VIKOR method, the decision matrix is formed. Since we have used the Gray VIKOR method, the VIKOR questionnaire completed by the experts must be first changed into the interval numbers using the Rough theory concept, and then calculations are performed using the Gray VIKOR method. In the following, the Gray VIKOR method is presented:

Step 1: Form the interval decision matrix obtained from the Rough theory;

$$D = \begin{bmatrix} [f_{11}^L f_{11}^U] & [f_{12}^L f_{12}^U] & \dots & [f_{1m}^L f_{1m}^U] \\ [f_{21}^L f_{21}^U] & [f_{22}^L f_{22}^L] & \dots & [f_{2m}^L f_{2m}^U] \\ [f_{n1}^L f_{n2}^U] & [f_{n2}^L f_{n2}^U] & \dots & [f_{nm}^L f_{nm}^U] \end{bmatrix} \quad (11)$$

Step 2: Determine the best (the most desirable) value f_j^* and the worst value f_j^- in each criterion of matrix D;

For a positive criterion (with the profit nature), the largest number shows the best value, and the smallest value shows the worst value;

$$f_j^* = \mathrm{Max}_i f_{ij}^U . f_{ij}^- = \mathrm{Min}_i f_{ij}^L \quad (12)$$

It is vice versa for a negative criterion (with the expense nature);

$$f_j^* = \mathrm{Min}_i f_{ij}^U . f_{ij}^- = \mathrm{Max}_i f_{ij}^L \quad (13)$$

In general, the best and the worst values are obtained as follows:

$$f_j^* = \{(\mathrm{Max}_i f_{ij}^U | j \in B) \mathrm{or} (\mathrm{Min}_i f_{ij}^L | j \in C)\} \quad (14)$$

$$f_j^- = \{(\mathrm{Min}_i f_{ij}^L | j \in B) \mathrm{or} (\mathrm{Max}_i f_{ij}^U | j \in C)\} \quad (15)$$

where *B* is a set of positive criteria, and *C* indicates a set of negative criteria.

Step 3: Calculate the values of $[S_i^L S_i^U]$ and $[R_i^L R_i^U]$;

$$S_i^L = \sum_{j\in B} W_j^L \left(\frac{f_j^* - f_{ij}^U}{f_j^* - f_j^-}\right) + \sum_{j\in B} W_j^L \left(\frac{f_{ij}^L - f_j^*}{f_j^- - f_j^*}\right) \quad (16)$$

$$S_i^U = \sum_{j\in B} W_j^U \left(\frac{f_j^* - f_{ij}^L}{f_j^* - f_j^-}\right) + \sum_{j\in B} W_j^U \left(\frac{f_{ij}^U - f_j^*}{f_j^- - f_j^*}\right) \quad (17)$$

$$R_i^L = \max_j \begin{cases} W_j^L \left|\frac{f_j^* - f_{ij}^U}{f_j^* - f_j^-}\right| & j \in B \\ W_j^L \left|\frac{f_{ij}^L - f_j^*}{f_j^- - f_j^*}\right| & j \in C \end{cases} \quad (18)$$

$$R_i^U = max_j \begin{cases} W_j^U \left|\frac{f_j^* - f_{ij}^L}{f_j^* - f_j^-}\right| & j \in B \\ W_j^U \left|\frac{f_{ij}^U - f_j^*}{f_j^- - f_j^*}\right| & j \in C \end{cases} \quad (19)$$

where W_j^L is the lower limit, and W_j^U indicates the upper limit of each criterion's weight.

Step 4: Calculate the values of $\left[Q_i^L Q_i^U\right]$;

$$Q_i^L = v\left(\frac{S_i^L - S^*}{S^- - S^*}\right) + (1-v)\left(\frac{R_i^L - R^*}{R^- - R^*}\right) \quad (20)$$

$$Q_i^U = v\left(\frac{S_i^U - S^*}{S^- - S^*}\right) + (1-v)\left(\frac{R_i^U - R^*}{R^- - R^*}\right) \quad (21)$$

where $S^* = \mathrm{Min}_i S_i^L$, $S^- = \mathrm{Max} S_i^U$, $R^* = \mathrm{Min}_i R_i^L$, and $R^* = \mathrm{Max}_i R_i^U$.

where Q is a cumulative index, and v indicates the weight of the maximum criterion policy and is expressed by $v \in [0.1]$: usually $v = \frac{0}{5}$.

Step 5: Rank choices according to S, R, and Q.

Since the Gray VIKOR method suggests the interval weights for the research choices, the weight of the choices, similar to the VIKOR method, cannot be easily ranked according to the Q index. In order to rank the interval weights, several ways are described below.

$$A = [a_1.a_2]; B[b_1.b_2] \quad (22)$$

$$C = [c_1.c_2] = A - B = [a_1 - b_2.a_2 - b_1] \quad (23)$$

$$IF \frac{|c_1|}{c_2 - c_1} < \frac{|c_2|}{c_2 - c_1} \rightarrow \text{Then } A > B \quad (24)$$

$$IF \frac{|c_1|}{c_2 - c_1} < \frac{|c_2|}{c_2 - c_1} \rightarrow \text{Then } A \leq B \quad (25)$$

12. Findings

In order to link the significant components of flexibility in the supply chain and competitive value integration propositions, meta-synthesis is used to enter the phase of the Rough analysis by formulating the identified components and propositions in the form of research matrix checklists in the quantitative part.

13. Meta-synthesis findings

The method of meta-synthesis through theoretical and research screening seeks to identify components and propositions related to the research topic. The period for analyzing similar research has been from 2017 to 2020. In other words, to find similar articles and research and use international and domestic research databases and references, research related to the research goal was identified.

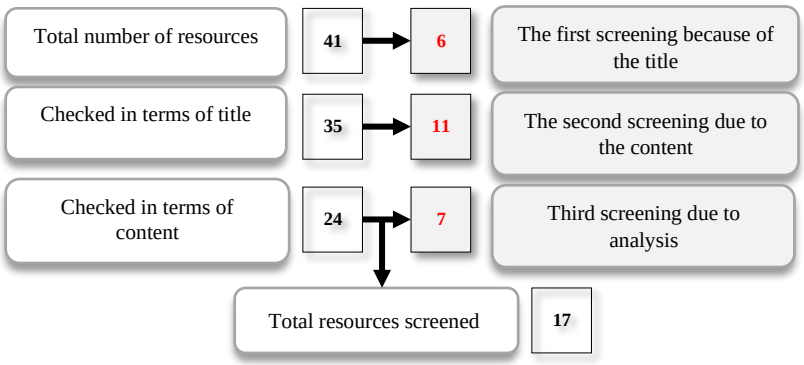

Figure 5. Screening of the initial research.

(**Source**: Research Findings)

As shown in Figure 5, all of the primary sources identified are 41, which 17 research relevant to the content, title, and analytical processes of this research were finally chosen after several stages of the screening process in terms of content, title, and analysis. In this stage, concepts should be broken down into components and propositions based on the Atttride-Sterling (2001) method to determine value integration based on supply chain flexibility in the form of scorecards. In fact, through the criterion of economic evaluation based on 10 criteria of research objectives, including the logic of research method, research design, sampling, data collection, reflectivity, the accuracy of the analysis, the theoretical and transparent expression of the findings, and the research value, part (A) determines the components of supply chain flexibility and part (B) determines integrating the values resulting from flexibility in the supply chain.

13.1 Identify components of supply chain flexibility (T)

In this section, according to the explanations given, the components of supply chain flexibility are identified with symbol (T). Table 1 evaluates components and indicators based on a 50-point index in the form of scores from 1 to 5 based on the 10 criteria described.

Table 1. The vital analysis process of the screened research.

Researches Status	Critical evaluation criteria / Researches	Research purposes	The logic of the research method	Research plan	Sampling	Collecting data	Reflexivity	Ethical considerations	Accuracy of analysis	Theoretical and clear expression of findings	The value of research	Total
International researches	Singh et al. (2020)	3	5	4	3	3	3	4	5	4	4	38
	Liao (2020)	4	4	4	4	4	4	4	3	4	4	39
	Irfan et al. (2019)	3	3	3	3	3	4	3	3	3	5	33
	Singh and Kumar (2019)	3	4	4	4	3	4	4	4	3	4	37
	Novais et al. (2019)	4	4	3	4	2	3	4	4	4	4	36
	Goyal et al. (2018)	4	3	3	4	3	3	3	4	4	4	31
	Rojo et al. (2018)	2	2	3	4	3	3	3	3	3	4	***21***
	Manders et al. (2017)	4	5	5	3	4	3	3	3	4	4	38
	Obayi et al. (2017)	3	4	5	4	3	3	2	3	3	4	30
Internal researches	Akbarzade et al. (2019)	2	3	3	3	4	3	3	3	4	4	32
	Sahebi and Gilani (2019)	3	2	3	2	3	3	3	2	3	4	***26***
	Meftahi et al. (2019)	4	5	4	4	3	4	4	3	5	4	39
	Aghaeipour et al. (2019)	2	3	2	1	1	3	1	2	1	4	***18***
	Abbasi Bastami et al. (2017)	3	3	3	3	4	4	3	3	4	4	34
	Aghaei and Aghaei (2018)	2	2	2	1	2	2	2	3	3	3	***23***

(Source: Research Findings)

The scores presented based on the fashion index showed four works of Rojo et al. (2018), Sahebi and Gilani (2019), Aghaeipour et al. (2019), and Aghaei and Aghaei (2018). Considering that they received less than

30 out of 50 points according to the guidelines for the adequacy of the score of this analysis, the studies having a score of 30 or higher were approved, eliminated, and therefore excluded from the review. Then, using the Atttride-Sterling method (2001), the components of supply chain flexibility were extracted. Accordingly, the following scoring method was used to determine the components of supply chain flexibility. Based on this method, all sub-criteria extracted from the text of approved articles were written in the table column. Then, in the row of each table, the names of the approved researchers were given. Based on each researcher's use of the sub-criteria written in the table column, symbol ☑ is inserted, then the scores of each ☑ were added together in the sub-criteria column; the scores above the average of the researches were selected as the research components.

Table 2. The process of determining the main components of research.

Researches Status	Researchers	The flexibility of financial resources	Information systems flexibility	Strategic flexibility	Operational flexibility	Structural flexibility	Environmental flexibility	Knowledge management flexibility	Marketing flexibility
International researches	Singh et al. (2020)	-	✓	-	-	-	-	✓	-
	Liao et al. (2020)	✓		✓	✓	-	✓	-	-
	Irfan et al. (2019)	✓	✓	-	-	✓	-	✓	-
	Singh and Kumar (2019)	✓		-	✓	-	-	✓	✓
	Novais et al. (2019)	-	✓	✓	-	✓	-	✓	✓
	Goyal et al. (2018)	✓		-	✓	-	-	-	✓
	Manders et al. (2017)	✓		-	-	✓	-	✓	-
	Obayi et al. (2017)	-	✓	✓	✓	-	-	-	✓
Internal researches	Akbarzadeh et al. (2019)	✓		-	✓	-	-	✓	✓
	Meftahi et al. (2019)	✓	✓	-	✓	-	✓	-	✓
	Abbasi Bastami et al. (2017)	✓	✓	-	✓	-	-	-	✓
Total		**8**	**6**	**3**	**7**	**3**	**2**	**6**	**7**

(**Source**: Research Findings)

Based on this analysis, seven components of knowledge management flexibility were identified; marketing flexibility, the flexibility of operation processes, the flexibility of financing, and the flexibility of the effectiveness of information systems were the most common and were therefore examined as the main criteria of the supply chain. In this section, after analyzing the theoretical foundations of the approved researches, each of the identified components is defined according to Table 3.

Table 3. Supply Chain Flexibility Components

Components	Definitions
Knowledge management flexibility	This level of flexibility refers to knowledge-based processes in developing production process functions to distribution and sales. As management systems seek to develop creativity and innovation by improving methods of doing work and acquiring and utilizing knowledge, the flexibility in knowledge management in the supply chain is strengthened. It increases the competitive advantage for the company (Novais et al., 2019).
Marketing flexibility	In this approach, the level of capabilities and capacities of the company from the marketing perspective to deliver products to potential customers is considered so that there is a good balance between the level of order with the volume of production and the presence of demanding or demanding customers. This level of flexibility also includes the level of ability of the company to effectively and efficiently manage warehouses, loading capacity, its distributors, and other distribution facilities in response to emerging market conditions (Obayi et al., 2017).
The flexibility of operation processes	The more agile the process of operations, the more capable it will be to produce better quality products at a lower cost in exchange for more significant benefits. In fact, it defines the flexibility of production processes in the supply chain, the technological level, and the ability to use available resources to produce quality products with characteristics, combinations, and volumes following different customers' characteristics to meet the demands of different markets (Liao, 2020).
Flexibility of financing	Another critical dimension of the supply chain is access to financial resources to pursue future investment plans and projects. As long as a company can access liquidity to invest in projects with a positive net present value, it can pursue the development of production infrastructure or create a new single line or new market, regardless of financial constraints, and to a reasonable level to pay more attention to competitive advantage (Irfan et al., 2019).
The flexibility of information systems effectiveness	At this level of flexibility, information flow and feedback infrastructures and the timely use of analyzed data for decision making are considered. Information systems seek to provide managers with a level of effectiveness of decision-making processes by creating a reference database to maximize the efficiency of stakeholders. The ability of the organization's information system to adapt to changing conditions, especially during unforeseen events, is one of the essential components of flexibility in the supply chain (Abbasi Bastami et al., 2017).

(**Source**: Research Findings)

13.2 Identify value integration propositions (P)

As in the above steps and following the critical evaluation method in this section, the integration of values resulting from supply chain flexibility is determined. According to the explanations given, the integration of values resulting from supply chain flexibility with symbol (P) is identified in this section. Table 4 evaluates the contents of a proposition based on an index of 50 points in the form of scores from 1 to 5 based on the 10 criteria described.

The scores presented based on the fashion index showed 4 studies by Hang et al. (2020), Lee et al. (2020), Khatami Firoozabadi et al. (2018), and Rashidi et al. (2017) out of a total of 12 initial studies. Considering the studies received less than 30 out of 50 points following the guidelines for the adequacy of the scores of this analysis, the studies having a score of 30 or higher were approved, eliminated, and therefore excluded from the review. Accordingly, the following scoring method is used to determine the components of supply chain flexibility. Based on this method, all sub-criteria extracted from the text of the approved articles are written in the column of the table, and then in the row of each table, the names of the approved research researchers are given. Based on each researcher's use of

the sub-criteria written in the table column, symbol ☑ is inserted, and then the scores of each ☑ are added together in the sub-criteria column; the scores above the average of the researches are selected as the research components.

Table 4. The process of the critical analysis of the screened research.

Research Status	Critical evaluation criteria / Researches	Research purposes	The logic of method	Research plan	Collecting data	Collecting data	Reflexivity	Ethical considerations	Accuracy of analysis	Theoretical and clear	The value of research	Total
Researches International	Huang et al. (2020)	2	3	2	3	3	4	3	3	3	3	**26**
	Liu et al. (2020)	3	4	3	2	2	3	3	3	3	3	**29**
	Oleghe (2019)	4	4	4	4	4	3	4	4	4	4	36
	Abdelkafi and Pero (2018)	3	4	4	4	3	4	4	4	3	4	37
	Zhu et al. (2018)	4	4	3	4	2	3	3	4	4	4	36
	Prasad et al. (2017)	3	5	4	3	3	3	4	5	4	4	38
	Gawankar et al. (2017)	3	4	5	4	3	3	2	3	3	4	30
Internal researches	Ebrahimi et al. (2020)	3	4	4	4	4	5	4	4	4	4	40
	Manoochehri et al. (2019)	3	3	3	4	5	٤	٤	4	4	4	36
	Khakbazan et al. (2018)	3	4	4	4	4	4	3	4	5	5	40
	Khatami Firoozabadi et al. (2018)	3	2	2	2	2	3	4	3	3	3	**27**
	Rashidi et al. (2017)	2	3	3	3	2	3	3	2	3	3	**26**

(**Source**: Research Findings)

Table 5. The process of determining the main components of research.

Status	Researchers	Customer interaction dynamics	Reduce waiting time and on-time delivery	Creating innovative values	Dynamics of relationship with suppliers	Reduce market and process conflicts	Demand-based management	Dynamics of warehousing management	Reduce start-up time	Effectiveness of investment decisions
International researches	Oleghe (2019)	-	-	-	✓	-	-	-	✓	✓
	Abdelkafi and Pero (2018)	-	✓	✓	✓	✓	✓	✓	-	✓
	Zhu et al. (2018)	-	✓	✓	-	✓	-	✓	-	✓
	Prasad et al. (2017)	-	-	✓	-	✓	-	✓	-	✓
	Gawankar et al. (2017)	-	✓	✓	✓	-	-	✓	-	-
Internal researchers	Ebrahimi et al. (2020)	✓	-	✓	✓	-	-	-	-	-
	Manoochehri et al. (2019)	-	✓	-	✓	✓	✓	-	-	✓

Status	Researchers	Customer interaction dynamics	Reduce waiting time and on-time delivery	Creating innovative values	Dynamics of relationship with suppliers	Reduce market and process conflicts	Demand-based management	Dynamics of warehousing management	Reduce start-up time	Effectiveness of investment decisions
	Khakbazan et al. (2018)	-	✓	-	✓	-	-	-	✓	✓
Total		**1**	**5**	**6**	**6**	**4**	2	**4**	**2**	***5***

(**Source**: Research Findings)

Based on this analysis, it was also identified that five statements of reduction of waiting time and timely delivery, demand-based management, creating innovative values, dynamics of relationship with suppliers, and the reduction of the driving time are most frequent. After analyzing the theoretical foundations of approved research, this section defines each of the identified propositions according to Table 6.

Table 6. Proposals for value integration.

Value integration propositions	Symbols	Definitions
Reduce waiting time and on-time delivery	P1	Timely delivery in compliance with the time specified in the delivery of the product, while satisfying customers' demands, acts as a stimulus to motivate the next interaction with the company. Shortening the waiting time shows the company's commitment to respecting the rights of customers to satisfy their demands (Abdelkafi and Pero, 2018).
Demand-based management	P2	Leading the market in terms of demand is one of the most critical strategies for integrating the value of leading companies in the competitive market because balancing demand with supply can prevent the existence of bubbles and market fluctuations that cause stagnation (Gawankar et al., 2017).
Creating innovative values	P3	Customer value will increase when their tastes and expectations are met, and even beyond that, to inspire innovative needs by using up-to-date knowledge, the necessary planning is done by the company in a competitive environment (Prasad et al., 2017).
Dynamics of relationship with suppliers	P4	The supply of raw materials for production is one of the most strategic processes in the supply chain, which requires interactions and effective presence of the company in communication channels with suppliers of raw materials. The greater the capacity to communicate with suppliers, the less pressure the company faces in the absence of raw materials in times of crisis, not indicating that that the production line is stopped based on losses (Abdelkafi and Pero, 2018).
Reduce start-up time	P5	Another of the most strategic functions of value integration is the short time required to produce a product or to set up a production line in general. The existence of this value can be decisive in gaining more company share of the market (Manoochehri et al., 2019).

(**Source**: Research Findings)

The Delphi analysis was used to reach the theoretical saturation point so as to determine the reliability and generalizability of competitive value integration propositions as a set and designated components of supply chain flexibility as a reference (according to the relationships defined in the Rough method). For this purpose, these statements and components were provided to experts in the form of a checklist of seven options for the survey. Table 7 presents the results of the Delphi analysis.

Table 7. The results of the Delphi analysis.

Identified components	The first round of Delphi			The second round of Delphi			Result
	Average	Coefficient of agreement	Standard deviation	Average	Coefficient of agreement	Standard deviation	
Knowledge management flexibility	5.30	0.64	0.45	5.50	0.80	0.94	**Confirm**
Marketing flexibility	5.10	0.55	0.63	5.20	0.60	0.72	**Confirm**
Flexibility of operation processes	6	0.80	0.55	6.20	0.85	0.63	**Confirm**
Flexibility of financing	5.20	0.60	0.56	5.50	0.75	0.66	**Confirm**
Flexibility of information systems effectiveness	5.10	0.55	0.78	5.10	0.58	0.82	**Confirm**
Reduce waiting time and on-time delivery	5.50	0.78	0.84	6.10	0.82	1.002	**Confirm**
Demand-based management	5.30	0.64	0.45	5.50	0.80	0.94	**Confirm**
Creating innovative values	6	0.80	0.55	6.20	0.85	0.63	**Confirm**
Dynamics of relationship with suppliers	5	0.50	0.96	5.10	0.55	0.80	**Confirm**
Reduce startup time	5.20	0.60	0.67	5.30	0.65	0.69	**Confirm**

(**Source**: Research Findings)

As it is known, all components and propositions in line with the nature of analysis and concept due to the participation of research experts in the form of panel members have the necessary theoretical adequacy because both in terms of scores obtained from the average and in terms of scores obtained from the agreement coefficient is approved by all of them.

14. Rough analysis

In this step, more noticeable coding is used to determine the weight of the criteria according to the separation of reference variables from member variables and to better understand and deduce them.

Table 8. Coding of components and propositions for the Rough analysis.

Purpose	Elements	Research component codes
Supply chain flexibility components	Knowledge management flexibility	T1
	Marketing flexibility	T2
	The flexibility of operation processes	T3
	Flexibility of financing	T4

Purpose	Elements	Research component codes
	The flexibility of information systems effectiveness	T5
Competitive value integration propositions	Reduce waiting time and on-time delivery	P1
	Demand-based management	P2
	Creating innovative values	P3
	Dynamics of relationship with suppliers	P4
	Reduce operating time	P5

(**Source**: Research Findings)

After forming the propositions and components of the research, it is time to calculate the weight of the research criteria using the gray hierarchical analysis process. For this purpose, after forming the pairwise comparison matrix of the problem, experts' opinions were collected. In the next step, the degree of incompatibility of each pairwise comparison matrix was determined. If the incompatibility of the pairwise comparison questionnaires is standard (less than 0.1), the next step can be started; otherwise, the pairwise comparison questionnaires are returned to the experts for review. After confirming the compatibility of the pairwise comparison questionnaires using Rough theory (Equations (1)–(6)), the experts' opinion was converted to distance numbers. Finally, the criteria were obtained using the weights in Equations (8)–(10). Table 9 tabulates the results obtained from the calculations of the gray hierarchical analysis process.

Table 9. Results of the Gray hierarchical analysis process.

Purposes	Weight of criteria		Elements	Weight of elements		The final weight of the elements	
	Lower limit (L)	Upper limit (U)		Lower limit (L)	Upper limit (U)	Lower limit (L)	Upper limit (U)
Components	0.49	0.76	Knowledge management flexibility	0.301	0.354	0.287	0.354
			Marketing flexibility	0.222	0.268	0.195	0.268
			Flexibility of operation processes	0.129	0.211	0.108	0.211
			Flexibility of financing	0.463	0.517	0.421	0.517
			Flexibility of information systems effectiveness	0.230	0.282	0.185	0.282
Propositions	0.64	0.81	Reduce waiting time and on-time delivery	0.155	0.237	0.131	0.235
			Demand-based management	0.414	0.535	0.398	0.535
			Creating innovative values	0.606	0.689	0.576	0.684
			Dynamics of relationship with suppliers	0.311	0.453	0.243	0.453
			Reduce startup time	0.262	0.293	0.241	0.264

(**Source**: Research Findings)

According to the final weight of each component and proposition, it is determined that the incompatibility values are below 0.1, based on which the second step of the rough analysis can be entered. After calculating the weight of the research criteria, the next step is to form a problem decision matrix. Experts' opinions on the status of each option in each of the criteria were first collected

using the VIKOR questionnaire to form the distance decision matrix presented in Table 10.

Table 10. Experts' opinion on each of the options based on each criterion.

The first participant					
	(P1)	**(P2)**	**(P3)**	**(P4)**	**(P5)**
T1	2	4	3	6	4
T2	3	5	5	6	4
T3	3	4	4	5	2
T4	2	1	4	6	2
T5	3	2	5	3	2

* Note: Due to the limited space of the paper, only the answer of a contributor is provided.

(**Source**: Research Findings)

After distributing and analyzing experts' opinions about the status of each option in each of the propositions, a decision matrix is formed to analyze the problem. The analysis of the views of 23 managers with experience in petrochemical companies as members of the target community in the quantitative sector must first be converted into distance numbers to form a problem-solving table. Equations (1)–(6) are used to convert score analyses to distance numbers. Table 11 presents the distance decision matrix obtained from the rough method.

Table 11. The distance decision matrix.

	(P1)		(P2)		(P3)		(P4)		(P5)	
	Lower limit (L)	Upper limit (U)	Lower limit (L)	Upper limit (U)	Lower limit (L)	Upper limit (U)	Lower limit (L)	Upper limit (U)	Lower limit (L)	Upper limit (U)
T1	10.28	12.44	20.84	22.17	18.74	20.32	14.35	16.07	17.66	19.23
T2	9.89	11.52	18.11	20.10	18.61	20.21	13.75	15.55	16.50	18.29
T3	13.86	15.77	19.04	21.66	20.16	21.95	16.05	17.82	17.15	18.96
T4	11.24	13.45	17.74	19.19	16.78	18.24	14.37	16.11	18.36	20.15
T5	9.67	11.41	19.56	21.89	19.01	21.52	15.70	17.30	17.91	19.53

(**Source**: Research Findings)

Based on the result of the distance decision matrix, the demand-based management propositions (P2), creating innovative values (P3), and reducing start-up time (P5) were considered the most compelling propositions of integration of competitive values of companies operating in the petrochemical industry. Then, to analyze the Gray VIKOR method, research options were reviewed and evaluated. The first step in the Gray VIKOR method after the formation of the decision matrix is to identify the values of positive ideal (f_j^*) and negative ideal (f_j^-) in each of the criteria of the decision matrix. Table 12 presents the results obtained.

Table 12. Determining the positive and negative ideals.

	(P1)	**(P2)**	**(P3)**	**(P4)**	**(P5)**

Positive ideal (f_j^*)	12.76	22.46	20.22	16.63	20.08
Negative ideal (f_j^-)	10.03	20.34	18.15	15.14	17.98

(**Source**: Research Findings)

As can be seen, none of the propositions has a higher negative ideal than the positive ideal, reflecting the effectiveness of all propositions in terms of supply chain flexibility. Nevertheless, based on the results, it was again confirmed that the three demand-based governance propositions (P2), creating innovative values (P3), and reducing start-up time (P5), as the most compelling propositions of the integration of competitive values of companies operating in the petrochemical industry, have a higher degree of desirability than the other propositions. However, to recognize the most influential dimension of supply chain flexibility in the petrochemical industry based on the competitive value propositions of companies operating in the petrochemical industry, one must rely on the Gray VIKOR method as the last step. Based on Equations (16)–(19), first, propositions S_i^U , S_i^L , R_i^U , and R_i^L are calculated; then, by specifying the propositions, the central proposition of Gray VIKOR, i.e., *Q*, determined by Equations (20) and (21) is used. Table 13 tabulates the calculation results.

Table 13. Analysis of Gray VIKOR method propositions.

Supply chain flexibility components	Code	S_i^U	S_i^L	R_i^U	R_i^L	Q_i^U	Q_i^L	Rank
Knowledge management flexibility	P1	0.527361	1.261317	0.213896	0.404428	0.287366	0.450030	Third
Marketing flexibility	P2	0.554720	1.284763	0.243887	0.421605	0.301628	0.523588	Forth
Flexibility of operation processes	P3	1.10263	1.906635	0.352651	0.571672	0.440372	0.702763	Fifth
Flexibility of financing	P4	0.414443	1.12379	0.182651	0.325502	0.183193	0.332694	First
Flexibility of information systems effectiveness	P5	0.493055	0.234539	0.188745	0.330564	0.216721	0.419085	Second
Assessment criteria	Propositions			S^*	S^-	R^*	R^-	
	The value of propositions			0.652410	3.40561	0.503451	1	

(**Source**: Research Findings)

Since proposition *Q* represents the most critical law in rough analysis, i.e., the most crucial feature for modifying or improving the components, this study determined it based on Table 14. *Q* related to the flexibility of operations processes (P3) is the highest among research components. However, according to the Rough analysis guidelines, the lowest *Q* value determines the central component, which is the inverse of Rough analysis. It was determined that the lowest component, financing flexibility (P4), is the most crucial component of supply chain flexibility. Moreover, in second place is the effectiveness of information systems (P5). In fact, this result shows that the most effective component of supply chain flexibility is the financing functions, which has the highest level of priority in the dimensions of supply chain flexibility and experiences the most remarkable strengthening under the influence of the propositions of the integration of competitive values of companies operating in the petrochemical industry.

15. Conclusions

Value integration based on supply chain flexibility is pursued today as one of the most important strategic considerations at the top levels of corporate governance in a competitive market environment. Thus, if it is not considered, it will affect all corporate activities according to market needs. Therefore, this study tried to identify the components of flexibility and the

propositions of integration of competitive values using the Rough set analysis so as to examine the degree of flexibility of the chain under the propositions of integration of competitive values of companies operating in the petrochemical industry. It can help the effective competitive functions of companies active in this field. Based on this, first, by using meta-synthesis analysis and theoretical screening in the content of similar researches, an attempt was made to identify the components and propositions of the research. Then, based on the Delphi analysis, an attempt was made to evaluate the theoretical adequacy of components and propositions. Afterward, based on the approved components and propositions, the research entered the Rough collection phase to determine the most effective propositions of the integration of competitive values of companies operating in the petrochemical industry and the most influential components of supply chain flexibility. The results can be interpreted in several sections in analyzing the obtained results. First, based on determining the most effective integration value propositions of companies operating in the petrochemical industry, it should be stated that the two demand-based management propositions and the creation of innovative values were identified as the most useful reference in integration values. This result indicates that competitive values with the development of innovation and creativity in product production help increase demand management in the market and enable the company as a market leader to control volatility and align with customer needs in environmental conditions. The turbulent economic conditions will provide the best answer to gain a more significant competitive advantage. Finally, it was found that among the components related to flexibility in the sustainable supply chain, two components of financing flexibility (P4) and information systems flexibility (P5) are the most effective in competitive conditions for supply chain flexibility of companies operating in the petrochemical industry. The flexibility of financing in the supply chain helps companies operating in the petrochemical industry have the necessary plans for the future advancement of their investment plans and projects, regardless of any financial constraints; thus, they can launch plans to launch a new production line in the shortest possible time or pursue new products. Having this flexibility as a competitive basis in the supply chain will allow the company to open its hands to the path of sustainable economic development by developing investment in its infrastructure to provide a level of efficient production processes to marketing in various international regions and access to new markets. On the other hand, the flexibility of information systems helps companies active in the competitive field of petrochemicals reduce their need for raw materials by recognizing new markets, obtaining more accurate information from the market, and adapting it to production processes while under inflation and sanctions. At the same time, it can respond to the market's ever-changing needs by providing timely information to production teams and various parts of the company. By creating a reference database and collecting data on operations and performance processes, these information systems provide managers with a level of effectiveness of decision-making processes to maximize returns to stakeholders: a return that may range from improving product quality to achieving new markets and even macroeconomic dimensions. The results obtained from the perspective of analytical and conceptual processes correspond with the works of Singh et al. (2020), Singh et al. (2019), Abbasi et al. (2017), Tachizawa and Gimenez (2009), and Naser Sadrabady et al. (2014). Based on the obtained results, it is suggested that companies active in the field of petrochemicals try to create new production lines to improve production processes and improve the quality of their products according to the needs of customers and the existence of opportunities and market threats. Having an ergonomic order in terms of space occupation and resources, the effectiveness of supply chain production processes can lead to greater profitability by reducing costs. On the other hand, try to make financial resources more accessible to invest in plans and projects by timely disclosure of financial information and improving the quality of financial reporting to gain the trust and confidence of banks and financial institutions and even foreign investors so as to pursue investment projects more effectively. These companies should also strive to develop infrastructure investments to collect data through cross-border teams and research and develop (R & D) teams, in line with the information they need to meet in today's competitive market environment. Furthermore, by dynamizing their analytical processes, which require interactions and the effectiveness of communication channels within the company, they should try to develop the level of flexibility of information systems and thus their competitive goals in terms of customer recognition, recognizing new markets, and recognizing production with newer methods. Regarding the limitations of this research, it should be noted that the research combines the content and theoretical part with the real perceptions of the managers of petrochemical companies. At the same time, a significant level of connection between theories and empirical facts can be pointed out. The lack of coverage

of all aspects of supply chain flexibility is acknowledged as there may be numerous strategic and operational insights in the face of competitive realities that play a role in creating value for companies' competitive advantages. Further, another limitation of this research is related to its general nature. It should be examined in different case situations and according to the structural characteristics of a particular company, and its results should be compared with other similar companies in this field. However, as a suggestion for future research, the analysis method presented in this study can be done for a specific case analysis to evaluate the flexibility in the direct value chain based on statistical data. Thus, by referring to the functions of analytical processes, the level of cost differences in dimensions can determine the various supply chains, based on which and through the formulation of codified strategies to control costs, appropriate actions are implemented. It may also be used to rank flexibility strategies along the indirect value chain for the dimensions of sustainable corporate development. Finally, it should be noted that this study opens the way for future research in two areas: 1) conducting practical case analyses and extracting unique propositions and 2) further refining the process method of supply chain operations and developing a decision support system at the process level, making it possible at the operational level.

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Appendix

A) Delphi analysis questionnaire

Elements	Code	Likert scale						
		1	2	3	4	5	6	7

Knowledge management flexibility	T1							
Marketing flexibility	T2							
The flexibility of operation processes	T3							
The flexibility of financing	T4							
The flexibility of information systems effectiveness	T5							
Reducing the waiting time and on-time delivery	P1							
Demand-based management	P2							
Creating innovative values	P3							
Dynamics of the relationship with suppliers	P4							
Reducing the operating time	P5							

B) Rough Set Questionnaire

Elements		T1	T2	T3	T4	T5	P1	P2	P3	P4	P5
Knowledge management flexibility	**T1**										
Marketing flexibility	**T2**										
The flexibility of operation processes	**T3**										
The flexibility of financing	**T4**										
The flexibility of information systems effectiveness	**T5**										
Reducing the waiting time and on-time delivery	**P1**										
Demand-based management	**P2**										
Creating innovative values	**P3**										
Dynamics of the relationship with suppliers	**P4**										
Reducing the operating time	**P5**										