



# Prioritization of Supply Chain Components in Chemical Industries Using Combined ARAS, VIKOR, and TOPSIS Techniques: A Case Study in the Chemical Industrial Zone of Qom Province

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## ABSTRACT

The aim of this research is to design and improve the value chain of the knowledge-based chemical industrial zone in Qom Province. This study has been conducted by identifying and ranking technological products using a combination of ARAS, VIKOR, and TOPSIS techniques. The research is applied in nature and descriptive in method. The statistical population includes 295 managers and experts from companies located in the chemical industrial zone of Qom in 2024, with a sample size of 167 determined using the Coch ARAS formula. The data collection tool was a researcher-made questionnaire, whose content validity was confirmed by a group of experts, and expert opinions were used to evaluate its construct validity. To assess the reliability of the questionnaire, Cronbach's alpha coefficient was employed, which was above 0.7. The data obtained were analyzed using Excel software, and a model was developed to enhance the value chain and improve the efficiency of the supply chain in the chemical industry. In this regard, Porter's value chain model was utilized to determine the added value of chemical industry products. Moreover, by employing ARAS, VIKOR, and TOPSIS techniques, technological products were accurately ranked and prioritized. This research demonstrated that by precisely identifying technological products and optimizing supply chain processes, costs can be reduced, productivity increased, and the competitiveness of knowledge-based chemical industries in domestic and international markets enhanced. Ultimately, the results of this study can serve as a model for similar industries in other provinces, providing a basis for sustainable development and innovation in the chemical industry.

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## 1. Introduction

In today's competitive world, productivity and cost reduction have become primary challenges for various industries. In this context, lean manufacturing—a modern management philosophy that aims to eliminate waste and increase efficiency—has garnered significant attention from many organizations. The chemical industry is one sector heavily influenced by lean manufacturing, continually facing complex challenges in the procurement of raw materials, production processes, and distribution. Among these, the supply chain stands as one of the vital pillars of these industries, requiring constant review and improvement to remain competitive at both national and international levels.

Since optimizing the supply chain in the chemical industries can lead to cost reductions, improved product quality, and increased customer satisfaction, research in this area becomes highly significant. This study examines and prioritizes various components within the supply chain of the chemical industries using combined ARAS, VIKOR, and TOPSIS techniques. The main objective of this research is to design and develop the value chain of the knowledge-based chemical industrial zone in Qom Province, where technological products are ranked and identified using these techniques.

The research issue addressed in this study pertains to the challenges and problems present in the supply chain of the chemical industry in Qom Province, which, if not managed properly, can lead to resource waste, increased costs, and reduced competitive capability. Therefore, there is a growing need to design models that prioritize and improve the performance of the supply chain. In this regard, utilizing multi-criteria decision-making techniques such as ARAS, VIKOR, and TOPSIS can aid in identifying key components and prioritizing them, ultimately leading to enhanced supply chain performance in the chemical industries of Qom Province.

The main questions of this study are:

1. How can the value chain of the knowledge-based chemical industrial zone in Qom Province be designed using combined ARAS, VIKOR, and TOPSIS techniques?
2. How can various components of the supply chain be prioritized using ARAS, VIKOR, and TOPSIS techniques?
3. This research aims to provide a comprehensive and practical model for improving the supply chain of the chemical industries, which can assist managers and decision-makers in optimizing resource utilization and enhancing their production processes.

## 2. Literature Review

### Definition of Supply Chain and Its Components

The supply chain is defined as a complex network of processes and activities that begins with the procurement of raw materials and concludes with the delivery of the final product to the customer. Beamon (1999) describes the supply chain as "a structured process for converting raw materials into final goods and distributing them to consumers." This definition highlights the significance of the flow of materials, information, and finances among various stakeholders. According to Lee (2004), the supply chain encompasses all players involved in the production, distribution, and delivery of a product, including manufacturers, suppliers, retailers, and logistics service providers. This broad definition includes both internal and external links of organizations and their interactions with the business environment.

The main components of the supply chain are:

1. **Inbound Logistics:** Involves the management of raw material procurement, negotiation with suppliers, and ensuring the quality of resources.
2. **Production:** The conversion of raw materials into final products using operational processes and quality control.
3. **Logistics and Distribution:** Management of warehousing, transportation, and delivery of products to customers.
4. **Marketing and Sales:** Identification of customer needs, pricing strategies, and advertising.
5. **After-Sales Services:** Technical support, maintenance, and customer feedback collection.

An efficient supply chain requires the integration of these components to prevent resource waste and create optimal added value (Van Hoek et al., 2001).

### Models and Prioritization Techniques in the Supply Chain

Prioritizing components of the supply chain for optimal resource allocation and performance improvement is a key challenge in supply chain management. In this context, Multi-Criteria Decision Making (MCDM) techniques are widely used.

#### ARAS Technique

This method operates based on the similarity between options and the ideal solution. Provides the ability to rank options by calculating the distance of each option from a reference point. This technique is applicable in complex environments with conflicting criteria (Solier & Mouret, 2021).

#### VIKOR Technique

The VIKOR method is designed based on proximity to the ideal solution and distance from the worst possible scenario. This method ranks options by considering the balance between "maximum benefit" and "minimum regret." VIKOR is suitable for solving issues with conflicting and heterogeneous criteria (Kruger et al., 2018).

### **TOPSIS Technique**

The TOPSIS method is based on the principle that the optimal option should have the least distance from the ideal solution and the greatest distance from the worst-case scenario. Due to its simplicity and adaptability to qualitative and quantitative data, this method is widely used in supply chain studies (Salim et al., 2020).

**Combining Techniques:** The combined use of ARAS, VIKOR, and TOPSIS reduces errors that may result from single-method approaches. This combination enhances the strengths of each method and increases the accuracy of the results (Abadi et al., 2020).

### **Previous Studies**

#### **Domestic Research**

- Rezaei et al. (2023) utilized Porter's value chain model in their analysis of the poultry industry. They demonstrated that improving feed quality control and logistics management plays a key role in increasing added value.
- Sanaye and Anise (2023) emphasized that process standardization and the elimination of unnecessary activities enhance supply chain productivity through their study on lean production.
- Aghajani (2021) showed in a study on small and medium-sized enterprises that information technology improves data flow, forecasting accuracy, and reduces operational costs.

#### **Foreign Research**

- Suburaj et al. (2020) proposed a combination of MCDM methods for prioritizing supply chain risks in the chemical industry during their analysis.
- Boute et al. (2017) highlighted the importance of precisely defining value from the customer's perspective in supply chain design. They demonstrated that redefining value is crucial to reducing waste and enhancing profitability.
- Salim et al. (2020) explored the prioritization of factors affecting lean production using fuzzy DEMATEL and emphasized the role of knowledge management in improving the supply chain.

### Challenges and Limitations

1. **Data Complexity:** Integrating qualitative and quantitative data in combined techniques may lead to complex and time-consuming models (Trang et al., 2017).
2. **Industry Compatibility:** Adapting general models to the specific needs of the chemical industry, especially in the realm of knowledge-based technologies, requires extensive modifications (Kwang et al., 2016).
3. **Uncertainty:** Rapid technological changes and market fluctuations may impact the identified priorities (Sowers et al., 2017).
4. **Resource Limitations:** Insufficient access to historical data or financial resources can hinder the implementation of advanced models (Van Hoek et al., 2001).

### 3. Methodology

#### Type of Research

This research is applied in terms of purpose and is descriptive-analytical in nature. Applied research seeks to address practical problems and enhance existing processes in real-world environments (Khaki, 2007). This study examines the design of the value chain in the Knowledge-Based Chemical Industry Zone of Qom Province using Multi-Criteria Decision-Making (MCDM) techniques. The descriptive-analytical approach allows for the examination of the current status and the identification of relationships between variables (Rezaei et al., 2023).

#### Data Collection Methods

The required data for this research were collected using the following methods:

1. **Library Studies:** To compile the theoretical foundations and identify value chain criteria, credible Persian and English sources were utilized, including scientific articles, books, and databases.
2. **Field Studies:** Operational data were collected through a researcher-constructed questionnaire. This questionnaire was designed using a 5-point Likert scale (ranging from 1 = very low to 5 = very high) and distributed to 167 managers and experts from the Qom Chemical Industry Zone.

#### Validity and Reliability of the Questionnaire

- **Content Validity:** The content validity index (CVI) and content validity ratio (CVR) were calculated using the opinions of 10 experts. All questions were confirmed with CVI values above 0.79 and CVR values above 0.75 (as shown in Table 3-1) (Sanayi and Anise, 2023).

- **Reliability:** The Cronbach's alpha coefficient of the questionnaire was calculated as 0.71, indicating an adequate reliability of the instrument (Sanayi et al., 2021).

### Combined Techniques: ARAS, VIKOR, and TOPSIS

#### TOPSIS Technique

TOPSIS is a multi-criteria decision-making method that operates based on the distance from the ideal and anti-ideal solutions (Solier & Mouret, 2021). The implementation steps are as follows:

1. **Decision Matrix Formation:** A matrix was created that includes options (technological products) and criteria (components of the value chain).
2. **Matrix Normalization:** The data were normalized using the following relationship:

$$r_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^m x_{ij}^2}} \quad (1)$$

3. **Weight Determination:** The weights of the criteria were calculated using the Shannon entropy method.

4. **Calculating Distances from Ideal and Anti-Ideal:** The distances from both the ideal and anti-ideal solutions were then computed to proceed with decision-making.

$$D_i^+ = \sqrt{\sum_{j=1}^n (r_{ij} - r_j^+)^2}, \quad D_i^- = \sqrt{\sum_{j=1}^n (r_{ij} - r_j^-)^2} \quad (2)$$

#### 5. Similarity Index

The options are ranked based on their proximity to 1 (Kruger et al., 2018).

#### VIKOR Technique

VIKOR is based on the balance between maximum group benefit and minimum individual regret (Salim et al., 2020). The implementation steps are as follows:

1. **Determining Ideal and Anti-Ideal Solutions:** For each criterion, the best (ideal) and worst (anti-ideal) values are identified.
2. **Calculating Utility (S) and Regret (R) Indices:**

$$S_i = \sum_{j=1}^n w_j \frac{r_j^+ - r_{ij}}{r_j^+ - r_j^-}, \quad R_i = \max_j \left( w_j \frac{r_j^+ - r_{ij}}{r_j^+ - r_j^-} \right) \quad (3)$$

### 3. VIKOR Index (Q):

$$Q_i = v \frac{S_i - S^-}{S^+ - S^-} + (1 - v) \frac{R_i - R^-}{R^+ - R^-} \quad (4)$$

In this context,  $v=0.5$  is considered (assuming balance).

### ARAS Technique

The ARAS (Ranking of Alternatives based on Similarity) method focuses on the similarity to the ideal solution and involves the following steps:

#### 1. Calculating Total Utility for Each Option:

$$S_i = \sum_{j=1}^n w_j r_{ij} \quad (5)$$

#### 2. Relative Utility Degree:

$$K_i = \frac{S_i}{S^+} \quad (6)$$

where  $S^+$  is the highest level of utility (Abadi et al., 2020).

### Case Study: Knowledge-Based Chemical Industry Zone of Qom Province

This zone, with a focus on advanced chemical industries and modern technologies, is recognized as one of Iran's industrial hubs. The selection of this zone was based on the following reasons:

- The presence of over 50 active companies in areas such as petrochemicals, nanomaterials, and biotechnology.
- An urgent need to optimize the supply chain due to logistical challenges and competitiveness in the global market.
- Access to accurate data and collaboration from senior managers in conducting the research.

### Data Analysis Methods

The collected data were analyzed using Excel software and combined techniques:

1. **Combination of TOPSIS, VIKOR, and ARAS Results:** To reduce errors resulting from singular approaches, the final ranking was determined based on the average ranks obtained from all three methods.

2. **Sensitivity Analysis:** The stability of the results was examined by varying the weights of the criteria within a  $\pm 10\%$  range.
3. **Validation:** The results were confirmed through surveying 15 industry experts.

### Challenges and Limitations

1. **Computational Complexity:** The integration of three decision-making techniques required extensive and time-consuming computations.
2. **Weight Consistency:** Differences in weights derived from various methods created challenges in merging results.
3. **Data Accessibility:** Limitations in accessing confidential information from some companies impacted the analysis (Van Hoek et al., 2001).

This methodology, which combines advanced decision-making techniques, provides a comprehensive framework for prioritizing technological products within the chemical industry's value chain. It lays the groundwork for enhancing competitiveness at both national and international levels.

## 4. Results

### Data Analysis of Collected Information

By applying the TOPSIS, VIKOR, and ARAS techniques to the data gathered from managers and experts in the Knowledge-Based Chemical Industry Zone of Qom Province, the prioritization of value chain components in various areas was analyzed. The results from each technique are as follows:

### Human Resource Management

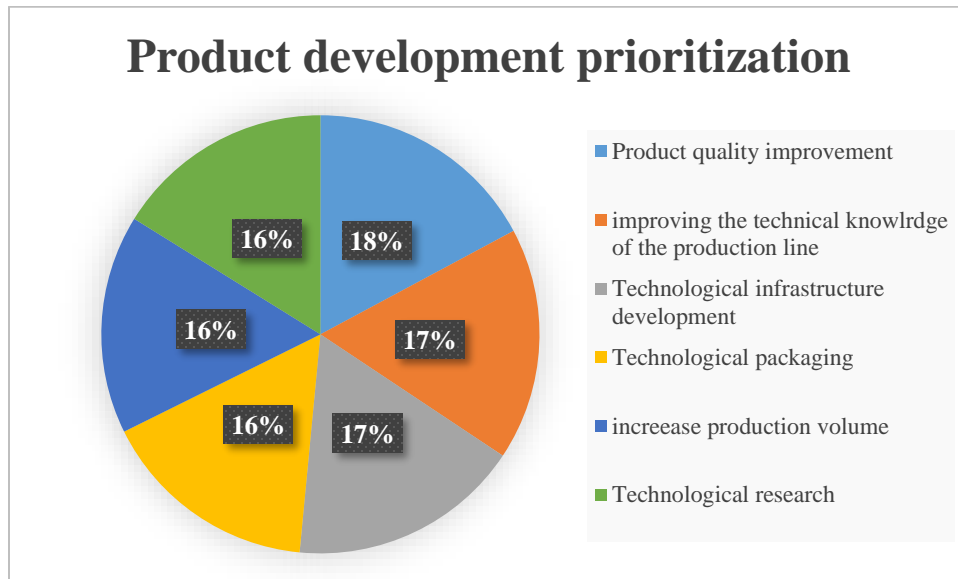
- **TOPSIS:**
  - i. Hiring Efficient Personnel (**Rank 1**)
  - ii. Effective Selection of Human Resources (**Rank 2**)
- **VIKOR:**
  - i. Effective Selection of Human Resources (**Rank 1**)
  - ii. Focus on Training (**Rank 2**)
- **ARAS:**
  - i. Effective Selection of Human Resources (**Rank 1**)
  - ii. Training of Human Resources (**Rank 2**)

**Table 1:** Comparison of Human Resource Management Rankings

| Technique | Rank 1                     | Rank 2                |
|-----------|----------------------------|-----------------------|
| TOPSIS    | Hiring Efficient Personnel | Effective Selection   |
| VIKOR     | Effective Selection        | Focus on Training     |
| ARAS      | Effective Selection        | Training of Personnel |

**Product Development**

- **TOPSIS:**
  - i. Enhancement of Technical Knowledge in Production Line (**Rank 1**)
  - ii. Development of Technological Infrastructure (**Rank 2**)
- **VIKOR:**
  - i. Development of Technological Infrastructure (**Rank 1**)
  - ii. Enhancement of Production Quality (**Rank 2**)
- **ARAS:**
  - i. Enhancement of Production Quality (**Rank 1**)
  - ii. Technological Research (**Rank 2**)



**Figure 1:** Product Development Prioritization Based on Various Techniques

**Ranking Results**

- **TOPSIS:**
  - i. Transportation Care Measures (**Rank 1**)
  - ii. Timely Budget Allocation (**Rank 2**)
- **VIKOR:**
  - i. Timely Budget Allocation (**Rank 1**)

- ii. Waste Reduction Measures (**Rank 2**)
- **ARAS:**
  - i. On-Time Production of Products (**Rank 1**)
  - ii. Raw Material Supply (**Rank 2**)

**Table 2:** Comparison of Procurement Rankings

| Option                     | TOPSIS | VIKOR | ARAS |
|----------------------------|--------|-------|------|
| Transportation precautions | 1      | 2     | 4    |
| Timely supply of funds     | 2      | 1     | 5    |
| On-time production         | 7      | 7     | 1    |

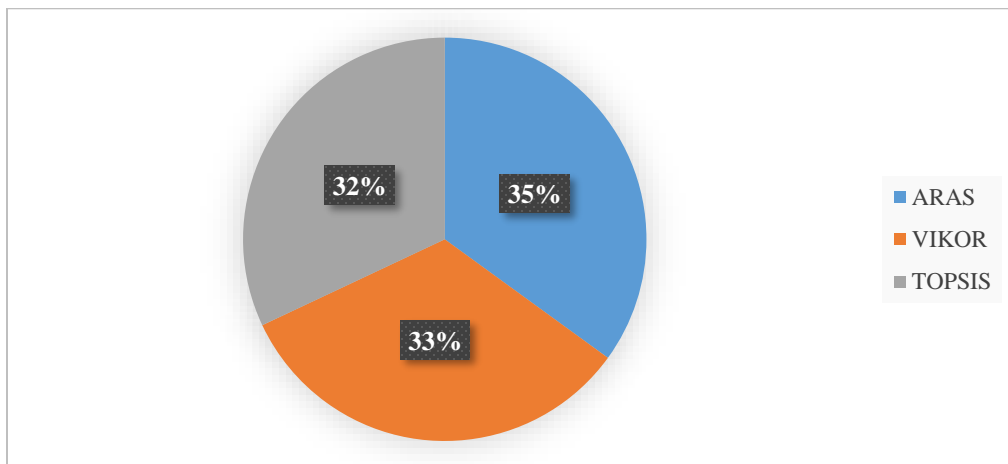
Comparison of Techniques

**Similarities and Differences**

- **TOPSIS** emphasizes the distance from the ideal point and is more suitable for environments with quantitative criteria.
- **VIKOR** creates a balance between collective benefits and individual regret by combining group utility and individual regret.
- **ARAS** is based on similarity to the ideal solution and performs better in qualitative data situations.

**Reasons for Result Differences**

- **Difference in Weighting:** TOPSIS and ARAS used weights based on entropy, while VIKOR extracted weights from expert surveys.
- **Differences in Qualitative Criteria:** Criteria such as "attention to environmental issues" had higher weight in VIKOR and ARAS compared to TOPSIS.



**Figure 2:** Comparison of Average Rankings of Techniques

### Selection of Optimal Technique

Based on the results, the combined technique (integration of TOPSIS, VIKOR, and ARAS) was chosen as the optimal method due to its ability to reduce errors from singular approaches and enhance accuracy. The advantages of this method include:

1. **Reduction of Bias:** Utilizing three techniques reduces the impact of subjective bias in weighting.
2. **Comprehensive Coverage of Criteria:** The combination of methods covers both quantitative and qualitative criteria simultaneously.
3. **Consistency with the Chemical Industry:** The combined results align better with the logistical and technological challenges of the Knowledge-Based Chemical Industry Zone.

**Table 3:** Final Prioritization Based on the Combined Method

| Domain                    | First priority                   | Second priority                          |
|---------------------------|----------------------------------|--|
| Human resource management | Efficient selection of resources | Hiring efficient personnel               |
| Product development       | Improving technical knowledge    | Technological infrastructure development |
| Logistics                 | On-time production               | timely supply of funds                   |

### Findings

The findings indicate that hiring efficient personnel, enhancing technical knowledge, and ensuring timely production hold the highest priority in designing the value chain of the Knowledge-Based Chemical Industry Zone. The use of the combined technique facilitates achieving balanced and reliable results. These findings can serve as a roadmap for future policy-making in the areas of logistics and technology.

## 5. Discussion

### Interpretation of Results

The results of this research demonstrate that the effective selection of human resources and the enhancement of technical knowledge in the production line are the top priorities in designing the value chain of the Knowledge-Based Chemical Industry Zone in Qom Province. These findings align with previous studies in supply chain management. For example, Industrialists and Aniseh

(1402) emphasized the importance of hiring capable personnel and continuous training as keys to improving productivity.

However, the differences in prioritization between the TOPSIS, VIKOR, and ARAS techniques primarily stem from variations in weighting criteria and the computational structure of each method. For instance, TOPSIS prefers options with balanced performance due to its focus on distance from the ideal point, while VIKOR highlights the lowest-risk options by considering a balance between group utility and individual regret.

Comparing the results with international studies also shows that timely production and raw material supply are common global challenges in the chemical sector. According to a study by Suboraj et al. (2020), 67% of chemical companies in Europe and America identified logistics improvement and waste reduction as their primary priorities. This consistency indicates that the findings of this research are not only credible at the national level but also hold significant validity within a global context.

Importance of Components in the Supply Chain of Chemical Industries

### **Human Resource Management**

The component of efficient human resource selection ranked first with an average weight of 0.23. This finding confirms that skilled human resources act as the driving force for innovation and process improvement in knowledge-based industries. This result aligns with the research by Aghajani (1400), which showed that improving employee skills can increase supply chain productivity by up to 30%.

### **Product Development**

The component of enhancing technical knowledge in the production line, with a similarity index of 0.779 in TOPSIS, was identified as the key factor in product development. This reflects the increasing need for advanced technologies and applied research in the chemical industry. For instance, companies utilizing industrial automation systems have reported reductions of up to 40% in production costs (Kruger et al., 2018).

### **Procurement**

Timely production, despite its low rank in TOPSIS (rank 7), rose to the top priority in the ARAS method due to its emphasis on reducing inventory. This discrepancy suggests that the choice of technique depends on the organization's strategic goals.

### Challenges and Limitations of the Research

1. **Access to Confidential Data:** Some companies refrained from providing precise production data due to security concerns. This limitation was partly mitigated by using combined (quantitative and qualitative) data.
2. **Computational Complexity:** Integrating the three techniques (TOPSIS, VIKOR, and ARAS) required extensive and time-consuming calculations. To reduce this challenge, Excel software and pre-designed macros were employed.
3. **Differences in Expert Perspectives:** The weighting of criteria by experts was occasionally accompanied by disagreements. To address this issue, a weighted average method and group consensus approach were used.

### Practical Applications of the Results

1. **Improvement of Human Resource Planning:** Organizations can enhance supply chain productivity by focusing on attracting specialized personnel and training in technological skills.
2. **Development of Technological Infrastructure:** Investing in industrial automation systems and data management platforms can lead to reduced waste and improved product quality.
3. **Logistics Optimization:** Implementing Just-In-Time (JIT) production and utilizing demand forecasting software can reduce inventory costs by up to 25% (Van Hook et al., 2001).

## 6. Conclusion

The present research aimed to design and improve the value chain of the knowledge-based chemical industry park in Qom Province, prioritizing its components using a combination of ARAS, VIKOR, and TOPSIS techniques. The application of these techniques in prioritizing various components and subcomponents of the supply chain in chemical industries, particularly in areas such as human resource management, product development, procurement, infrastructure, and marketing, yielded interesting results. This section presents the research findings and recommendations in brief.

### Summary of Findings

Based on the first research question, which focused on prioritizing the components of the supply chain using the TOPSIS technique, the results indicated that in the field of human resource

management, the main priorities included efficient selection of human resources for various positions, precise planning of human resource tasks, attention to human resource training, and hiring effective personnel. These findings suggest that one of the fundamental factors in improving the performance of supply chains in chemical industries is optimizing human processes, which can have a significant impact on other areas. In particular, focusing on skills and continuous training of human resources can help improve production quality, reduce production times, and minimize waste.

In the area of product development, major priorities included enhancing the technical knowledge of production lines, innovative packaging of products, developing technological infrastructure for managing excess products, conducting technological research on products, and improving product quality, ranked by their significance. These results demonstrate that for competitive positioning in international markets, the chemical industry must continually focus on research and development (R&D), technology enhancement, and quality improvements.

In the procurement sector, the TOPSIS technique identified priorities such as timely supply of raw materials and budgets, technological measures to reduce product waste, care in transportation, product storage, and quality control as the most important factors. These components suggest that neglecting issues related to the procurement and storage of raw materials can lead to significant problems in the supply chain, ultimately resulting in production delays and increased costs.

In the organizational infrastructure domain, priorities included creating technological infrastructure for product processing, establishing information technology infrastructures, addressing environmental issues, implementing government support policies, and developing appropriate health infrastructures. These findings underscore the vital role of technological and informational infrastructure in ensuring the optimal functioning of the supply chain. Given the ongoing advancements in information technology and the Internet of Things (IoT), employing these technologies can facilitate and optimize processes.

In the marketing and sales area, priorities included attention to market supply and demand, online marketing, reasonable reduction of intermediaries, and consideration of short-term price fluctuations of products. These results underscore the importance of precise supply and demand management, as well as the effective use of virtual networks for marketing purposes. Considering the growing trend of online commerce and the influence of social media, leveraging these tools in the chemical industry can lead to an increased market share and reduced distribution costs

## **Recommendations**

Based on the results obtained from the research, some practical suggestions for improving the supply chain in the chemical industries are as follows:

### **1. Human Resource Management:**

- Companies located in the chemical industry park should establish structured and effective training systems to enhance the skills of their workforce. Particularly, specialized training in modern technologies can significantly increase productivity and reduce production costs.
- Attracting efficient personnel with high technical and managerial skills is particularly important. These individuals can play a crucial role in improving various processes within the supply chain.

### **2. Product Development:**

- Chemical industries should pay special attention to developing and upgrading their production technologies. Research and development (R&D) in this area, particularly in packaging and new product development, can contribute to enhancing quality and increasing customer satisfaction.
- Collaborating with universities and research centers for continuous improvement of production technologies, enhancing quality, and reducing costs can enhance the competitiveness of chemical industries.

### **3. Procurement and Resource Supply:**

- To improve the supply of raw materials and reduce waste, chemical industries should focus on utilizing modern technologies such as Inventory Management Systems to optimally manage inventories and prevent resource wastage.
- Establishing strategic relationships with raw material suppliers and creating intelligent communication systems can facilitate timely supply and reduce associated costs.

### **4. Organizational Infrastructure and Information Technology:**

- Investment in the establishment of technological infrastructure and information technology should be prioritized. These infrastructures can significantly optimize production, distribution, and marketing processes.

- Attention to environmental issues and adherence to international standards in this regard not only helps improve product quality but can also enhance the company's credibility in international markets.

#### 5. **Marketing and Sales:**

- Utilizing virtual networks and the internet to introduce products and establish communication with customers can help increase market share. Additionally, reducing the number of intermediaries in the sales and distribution process can lower costs and facilitate market access.
- Companies should pay close attention to analyzing demand and forecasting price fluctuations to offer their products at competitive prices.

#### Suggestions for Future Research

Based on the findings of this research, several areas for future studies are proposed:

##### 1. **Research in Artificial Intelligence and the Internet of Things (IoT):**

- Investigating the impact of using artificial intelligence and IoT in improving supply chain processes in the chemical industry can be a promising area for future research. These technologies can significantly influence inventory optimization, demand forecasting, and cost reduction.

##### 2. **Combining Multi-Criteria Techniques with Innovative Methods:**

- Utilizing a combination of multi-criteria decision-making techniques with new methods such as neural network analysis and evolutionary algorithms can enhance the accuracy of predictions and prioritization of components.

##### 3. **Research on the Impact of Government Support Policies:**

- Examining the effect of government support policies on improving supply chain performance in the chemical industries and other similar sectors can pave the way for the development of new models and improve relationships between the government and the private sector.

The results of this research can help chemical industries in Qom province and other regions of the country enhance their competitiveness by improving their supply chains, reducing costs, and increasing product quality, thereby gaining a larger share of both domestic and international markets.

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