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# Cross-Efficiency and Multi-Criteria Decision-Making for the Selection of Third- and Fourth-Party Logistics Services with a Green Supply Chain Management Approach

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**Abstract**

This study aims to determine third-party (3PL) and fourth-party (4PL) logistics services based on green supply chain management using cross-efficiency and multi-criteria decision-making. In today's competitive environment, improving the performance of construction companies, especially in alignment with green supply chain objectives, is an essential necessity. In this research, the Analytic Hierarchy Process (AHP) was employed to determine the weights, and the Data Envelopment Analysis (DEA) method was used for ranking. Several companies from the Rasht Industrial City were selected for analysis, and the opinions of 10 experts were collected both qualitatively and quantitatively. The results showed that economic, environmental, and social factors were identified as the most important elements influencing the implementation of 3PL and 4PL services in the construction industry. This study, by providing a comprehensive framework for performance evaluation in the construction industry, emphasizes the importance of considering environmental components in enhancing organizational efficiency and competitiveness.

**Keywords:** Logistics, Cross-efficiency, Green Supply Chain, Multi-criteria Decision-making, Data Envelopment Analysis.

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# 1. Introduction

In today's world, supply chain management has become one of the key factors in improving organizational performance and enhancing competitiveness. With the growing expansion of global trade, companies are seeking solutions to optimize logistics processes and reduce operational costs. In this regard, the utilization of third-party logistics (3PL) and fourth-party logistics (4PL) has gained significant attention as efficient strategies for outsourcing logistics operations [1].

In recent years, the increasing intensity of competition in global markets has compelled organizations to pursue continuous improvement of their performance. Among these, the construction industry—as one of the largest and most influential sectors in national economies—plays a vital role in sustainable development. Optimizing processes within this industry, especially in the domain of supply chain management, has become particularly important in reducing costs, improving quality, and enhancing environmental indicators.

Given the growing global concerns about environmental pollution and the excessive consumption of natural resources, the need to adopt a green supply chain has become more pressing than ever. Accordingly, evaluating the efficiency of companies active in the construction industry by considering economic, operational, and environmental criteria is a critical step toward sustainable development [2].

Data Envelopment Analysis (DEA), as a widely used tool for measuring the relative efficiency of decision-making units, allows for multi-criteria evaluation without the need for predefined weights, for more information about DEA models in different industries see [3-7]. On the other hand, the Analytic Hierarchy Process (AHP), by structuring decision-making criteria, greatly assists in determining weight priorities among various indicators. The integration of these two methods provides a suitable framework for evaluating and ranking companies' efficiency based on multiple objectives, particularly within the scope of green supply chain management.

The primary aim of this study is to explore how multi-criteria decision-making approaches can be used to evaluate and select logistics service providers (3PL and 4PL) based on green supply chain management indicators.

## 2. Literature Review

### 2.1 Logistics

Logistics refers to a set of coordinated activities aimed at planning, implementing, and efficiently controlling the flow of goods, services, and information from the point of origin to the final consumer. This process encompasses areas such as transportation, warehousing, inventory management, packaging, and order processing, with the ultimate goal of reducing costs, shortening delivery time, and improving customer satisfaction. According to the Council of Logistics Management, logistics is the process of planning, implementing, and controlling the effective flow and storage of goods, services, and related information from the point of origin to the point of final consumption [8].

In this regard, Rahimi et al. (2021) examined the key components of logistics in the establishment of a logistics center in Iran's Markazi province. Using a descriptive-applied approach and field data along with thematic analysis, they identified the logistics components and analyzed their interrelationships through the DEMATEL method [8]. Additionally, Zarrindast et al. (2018) focused on the closed-loop supply chain for lead-acid batteries, utilizing system dynamics to model capacity planning decisions. The model was able to simulate and analyze the impact of various policies on supply chain performance [9]. In a related study, Ghaemi-Asl et al. (2022) proposed an optimized model based on an iterative local search metaheuristic algorithm, designed around the performance of fourth-party logistics (4PL) companies. This model was developed to predict backup routes ensuring transport network security and on-time delivery, significantly contributing to the reduction of total logistics costs [10].

### 2.2 Green Supply Chain Management and Sustainability

Green Supply Chain Management (GSCM) is an integration of classical supply chain management concepts and environmental principles, developed with the goal of minimizing negative environmental impacts at various stages of the supply chain. This approach includes a wide range of activities such as sustainable design, eco-friendly sourcing, efficient and low-consumption production, low-carbon transportation, waste management, and recycling. The main objective of GSCM is to reduce resource consumption, increase energy efficiency, minimize pollution, and enhance the overall sustainability of the supply chain [11].

In this context, the concept of green productivity is introduced as an effective tool for improving environmental performance in organizations. Through waste reduction, reuse, and recycling, green productivity enhances the quality and efficiency of goods and services. As a result, it not only increases organizational profitability but also creates sustainable competitive advantages by reducing production and operational costs [12].

In a study by Chineiforush et al. (2010) in Iran’s petrochemical industry, the role of green supply chain in improving organizational performance was examined. The results showed that environmental collaboration in the supply chain has a significant impact on improving operational aspects such as cost reduction, quality enhancement, delivery time improvement, and reduced environmental impacts. Furthermore, technological and logistical integration within the green supply chain plays a crucial role in strengthening organizational mechanisms and enhancing performance [13].

In another study, Shafiei and Taramest (2013) investigated the impact of green supply chain management processes on competitive advantage and organizational performance at SAPCO. The findings indicated significant relationships between strategic cooperation with suppliers, customer relationships, and the quality of products and services, with improved performance in terms of price, environmental product quality, innovation, and efficiency [14].

Tarian et al. (2022), using a qualitative approach and meta-synthesis method, identified the components influencing the implementation of green supply chain management in the construction industry. These components were categorized into four main groups: key managerial factors, facilitators, internal and external drivers, and internal and external barriers [15].

In a recent study, Zarei et al. (2024) proposed a comprehensive model to define the key success factors in implementing green supply chain management in Iran’s construction sector. This model, by emphasizing the alignment of supply chain processes with environmental sustainability goals, provides practical solutions for industrial managers and researchers, and identifies essential elements for the success of this approach [16].

### 2.3 Multi-Criteria Decision Making

Multi-Criteria Decision Making (MCDM) is a major branch of decision science where optimal selection is made among multiple alternatives, considering several—often conflicting—criteria. This approach is applied when decision-makers face both qualitative and quantitative indicators and need to choose the most appropriate option based on a combination of criteria. MCDM provides analytical tools for comprehensive evaluation and helps decision-makers make logical and optimal decisions.

In this study, a combination of the Analytic Hierarchy Process (AHP) and Data Envelopment Analysis (DEA) has been used to prioritize criteria and assess the efficiency of decision-making units. Within this framework, AHP is used to determine the weight of each criterion based on expert opinion, while DEA assesses the relative performance of the units using these weights.

In a study conducted by Jamassbi et al. (2023), key indicators for selecting sustainable third-party logistics providers in the dairy industry were identified and analyzed. The fuzzy Delphi method was used for the initial screening of indicators based on expert opinion, followed by fuzzy AHP to determine relative weights. Subsequently, the COCO-SO method was used for the final evaluation of supplier performance. The findings revealed that timely delivery and transportation costs had the highest importance, and Company No. 3 performed better than others in terms of sustainability indicators [17].

Similarly, Keramat et al. (2024) analyzed the impact of green technology on the sustainable performance of knowledge-based companies, exploring the mediating role of smart logistics and the moderating role of green governance. The statistical population included managers of knowledge-based companies in East and West Azerbaijan provinces. The results showed that green technology had a positive and significant impact on sustainable performance and the development of smart logistics. Moreover, smart logistics directly enhanced sustainable company performance [18].

In another study, Hoseinzadeh-Saljouqi et al. (2024) proposed a novel approach for fair allocation of fixed costs among competitive units in a supply chain. Using DEA and an enhanced version of cross-efficiency, the study addressed equitable resource allocation in single-stage and two-stage supply chains. The advantage of this method lies in its ability to preserve or enhance efficiency while considering both cooperation and competition among units, thereby reducing the computational complexity of traditional methods [19].

## 3. Modeling

Assume there are $n$ decision-making units (DMUs), such that the $j-th$ DMU uses a non-negative and non-zero input vector $X_j = (x_{1j}, \dots, x_{mj})$ to produce a non-negative and non-zero output vector $Y_j = (y_{1j}, \dots, y_{sj})$. As mentioned in Chapter 2, in classical Data Envelopment Analysis (DEA) models, the input and output weights are determined by the model itself. However, in real-world problems, there is often a relative importance or preference among inputs and outputs. In such cases, weight restrictions can be incorporated into the multiplier form of DEA models. The general form of weight restrictions is presented in Model (1):

$$\begin{cases} AU \leq b \\ BV \leq d \\ AU + BV \leq d \end{cases} \qquad (1)$$

In this study, weight restrictions were defined based on expert opinions.

It is important to note that in practical applications where the number of DMUs is small and the number of evaluation indicators is large, one way to enhance the discrimination power among the DMUs is to add weight restrictions. The inclusion of such restrictions shrinks the feasible region of the multiplier model, leading to lower efficiency scores (further from 1), since the objective function (efficiency score) will not improve under these constraints.

Since the primary goal of this study is to rank the DMUs, the cross-efficiency evaluation method was chosen. This method avoids infeasibility issues associated with super-efficiency models and is more stable and robust in practice.

Given that some of the outputs in this study are undesirable, let us define $y_j = \begin{pmatrix} y_j^g \\ y_j^b \end{pmatrix}$, where $y_j^g$ denotes the vector of desirable (good) outputs and $y_j^b$ denotes the vector of undesirable (bad) outputs. Under these conditions, in the cross-efficiency evaluation method, Model (2) is first solved for the evaluation of $DMU_P$.

$$\begin{aligned} & E_p^* = Max \sum_{r=1}^{s'} u_r y_{rp}^g \\ s.t. \quad & \sum_{r=1}^{s'} u_r y^g{}_{rj} - \sum_{i=1}^{m} v_i x_{ij} - \sum_{r=s'+1}^{s} u_r y^b{}_{rj} \leq 0, && j = 1,...,n \\ & \sum_{i=1}^{m} v_i x_{ip} = 1 && (2) \\ & \sum_{i=1}^{m} \alpha_{it} v_i \leq b, && t = 1,...,T \\ & \sum_{r=1}^{s} \beta_{rl} u_r \leq d, && l = 1,...,L \\ & u_r \geq \varepsilon, && r = 1,...,s \\ & v_i \geq \varepsilon, && i = 1,...,m \end{aligned}$$

In Model (2), it is assumed that $s'$ the first component of the output vector corresponds to the desirable output, and $s - s'$ the last component corresponds to the undesirable output.

Suppose the optimal solution to Model (2) when evaluating $DMU_P$. is $(V_p^*, U_p^*)$. Then, using these optimal weights, the efficiency of all other DMUs is calculated based on the following equation:

$$E_{pj} = \frac{\sum_{r=1}^{s'} u_{pr}^* y^g{}_{rj}}{\sum_{i=1}^{m} v_{pl}^* x_{ij} + \sum_{r=s'+1}^{s} u_{pr}^* y^b{}_{rj}} \qquad (3)$$

By solving the optimization problem for all DMUs, a matrix is obtained:

| | | | |
|---|---|---|---|
| $E_{11}$ | $E_{12}$ | ... | $E_{1n}$ |
| $E_{21}$ | $E_{22}$ | ... | $E_{2n}$ |
| $\vdots$ | $\vdots$ | | $\vdots$ |
| $E_{n1}$ | $E_{n2}$ | ... | $E_{nn}$ |

This matrix is referred to as the cross-efficiency matrix. Note that:

$$E_{pp} = E_p^*$$

The $k - th$ column of this matrix shows the efficiency performance of $DMU_k$ under the optimal weights derived from each of the other DMUs. The ranking criterion is based on the following equation:

$$R_k = \frac{1}{n} \sum_{i=1}^{n} E_{ik} \qquad (4)$$

In essence, $R_k$ represents the average efficiency score of $DMU_k$ when evaluated using the optimal weights of all DMUs. The higher the $R_k$, the better the ranking of $DMU_k$.

In the modeling approach adopted in this study, two assumptions—along with the classical DEA assumptions—were incorporated:

- First assumption: Presence of undesirable outputs in the problem
- Second assumption: Incorporation of weight restrictions

By integrating these assumptions, the model was developed, and the cross-efficiency method was adapted accordingly.

## 4. Findings

In this study, the decision-making units (DMUs) include five third- and fourth-party logistics service providers (3PL/4PL) operating within the construction industry. These companies are:

- Paya Saman Pars Construction Company
- Omran va Maskan Iran Construction Company
- Padidehsazi Construction Company
- Kayson Construction Company
- Iranian Atlas Construction Company

In the first step, the criteria for evaluating sustainable logistics service providers were identified. These criteria were categorized into three main dimensions: economic, environmental, and social. A detailed breakdown of these indicators, along with their respective components, is presented in Table 1.

**Table 1**: Identified Components and Their Variables

| Dimension | Variables |
|---|---|
| **Economic** | Cost<br>Quality<br>On-time delivery<br>Technology<br>Financial performance<br>Risk management<br>Geographical location |
| **Environmental** | Environmental management system<br>Resource consumption<br>Green technology<br>Environmental pollutant emissions<br>Eco-design<br>Green transportation<br>Hazardous and dry waste management |
| **Social** | Employee health and safety<br>Customer satisfaction<br>Impact on local communities<br>Flexible work contracts<br>Job stability and security<br>Shareholders' rights |

To identify the influential indicators, the Fuzzy Delphi technique was employed. In this process, a questionnaire consisting of preliminary indicators was developed and distributed among 10 experts active in the industry to collect and analyze their professional opinions. After finalizing the indicators, the Fuzzy Analytic Hierarchy Process (FAHP) was used to determine their weights and prioritize them. For this purpose, a pairwise comparison questionnaire was sent to 8 experts, and the collected data were analyzed using fuzzy logic.

In the final step, to evaluate the performance of the suppliers, Data Envelopment Analysis (DEA) with a cross-efficiency approach was utilized. In this method, the finalized indicators (listed in Table 1) were classified into inputs and outputs based on expert opinion. This classification is reported in Table 2. Then, using the cross-efficiency DEA model, the relative performance of each supplier was assessed and compared.

One important consideration in Data Envelopment Analysis (DEA) is how to deal with undesirable outputs. In this study, one of the environmental indicators—namely the level of pollutant emissions—is considered as an undesirable output. Unlike other outputs where an increase is desirable, in this case, a reduction in the indicator value signifies better performance. In DEA models, various approaches exist for handling such indicators. One of the most common approaches is to treat the undesirable output as an input in the DEA model in order to maintain the direction of optimization.

In DEA models, unlike methods such as AHP or Super Decisions, the weights of the indicators are determined by the model itself based on an optimistic approach. This feature eliminates subjective managerial influence; however, it may sometimes fail to accurately reflect the complex realities of the system. Conversely, in methods such as AHP, expert and managerial opinions play a direct role in assigning weights to indicators, which can introduce bias or deviate from reality.

**Table 2**: Classification of Input and Output Indicators for the Evaluated Suppliers

| Code | Input/Output | Sub-Indicator | Main Category |
|---|---|---|---|
| $I_1$ | Input | Cost | Economic |
| $O_1$ | Output | Quality | |
| $O_2$ | Output | On-time delivery | |
| $I_2$ | Input | Technology | |
| $O_3$ | Output | Financial performance | |
| $O_4$ | Output | Risk management | |
| $I_3$ | Input | Geographical location | |
| $I_4$ | Input | Environmental management system | Environmental |
| $I_5$ | Input | Resource consumption | |
| $O_9 - b$ | Output | Environmental pollutant emissions | |
| $I_6$ | Input | Green transportation | |
| $I_7$ | Input | Dry waste management | |
| $O_6$ | Output | Employee health and safety | Social |
| $O_7$ | Output | Flexible work contracts | |
| $O_8$ | Output | Job stability and security | |
| $O_5$ | Output | Shareholders' rights | |

To address the weaknesses of each method, this study employs a hybrid approach, combining expert opinions for determining indicator weights with DEA models for evaluating the efficiency of decision-making units. The results from the Fuzzy Analytic Hierarchy Process (FAHP) were used to derive indicator weights and incorporate them into the DEA model.

Using Table 2, the weights of the economic, environmental, and social indicators were extracted and then incorporated into the model through Equations (5) and (6), which separate inputs and outputs. To prevent the complete exclusion of some indicators from the model, a very small value called $\varepsilon$ (epsilon) was introduced in Model (7). This small positive value ensures that no indicator receives a weight of zero, thereby guaranteeing that all indicators are considered in the analysis.

$$u_{2j} \geq u_{3j} \geq u_{4j} \geq u_{1j} \qquad (5)$$
$$u_{6j} \geq u_{9j} \geq u_{8j} \geq u_{7j}$$

$$u_{4j} \geq u_{6j} \geq u_{7j} \geq u_{5j} \qquad (6)$$
$$u_{1j} \geq u_{3j} \geq u_{2j}$$

Thus, constraints (5) and (6) are added to the cross-efficiency model, resulting in Model (7).

$$
\begin{aligned}
Max \quad & \sum_{r=1}^{8} u_r y_{rp} \qquad (7)\\
s.t. \quad & \sum_{i=1}^{6} v_i x_{ip} = 1 \\
& \sum_{r=1}^{8} u_r y_{rj} - \sum_{i=1}^{6} v_i x_{ij} - u_9 y_{9j} \leq 0, \quad j = 1,...,5 \\
& \begin{cases} u_{2j} \geq u_{3j} \\ u_{3j} \geq u_{4j} \\ u_{4j} \geq u_{1j} \end{cases}, \\
& \begin{cases} u_{6j} \geq u_{9j} \\ u_{9j} \geq u_{8j} \\ u_{8j} \geq u_{7j} \end{cases}, \\
& \begin{cases} u_{4j} \geq u_{6j} \\ u_{6j} \geq u_{7j} \\ u_{7j} \geq u_{5j} \end{cases}, \\
& \begin{cases} u_{1j} \geq u_{3j} \\ u_{3j} \geq u_{2j} \end{cases}, \\
& u_r \geq \varepsilon, v_i \geq \varepsilon \ , r = 1,...,9 \ , \ i = 1,...,6.
\end{aligned}
$$

Given that this study considers five decision-making units and sixteen evaluation indicators, using classical DEA models may lead to a fundamental issue: most DMUs could be identified as efficient. In such scenarios, the model would fail to make meaningful distinctions among the performances of the units, rendering the results practically useless for managerial decision-making.

Within the theoretical framework of DEA, one effective solution to this problem is the addition of weight restrictions to the model. Implementing these restrictions prevents the model from assigning arbitrary and unfair weights to indicators, thus improving its ability to differentiate between units.

In this study, weight restrictions were identified based on expert opinions in the fields of logistics and supply chain management and were incorporated into the DEA model. As a result, Model (4) was developed, which includes eleven specific weight restrictions. The implementation of these restrictions improved the analytical precision and enhanced the model's ability to rank decision-making units more accurately.

Finally, using the refined model, the aggregate efficiency of the decision-making units was calculated, and the final ranking of third-party and fourth-party logistics service providers was presented in Table 3.

**Table 4-12.** Final Ranking of the Providers

| Company Name | Efficiency Score | Rank |
|---|---|---|
| Iranian Atlas Construction Company | 0.62454 | 5 |
| Kayson Construction Company | 0.93436 | 4 |
| Padideh Sazi Construction Company | 0.9895 | 3 |
| Iran Housing and Urban Development Co. | 0.99838 | 1 |
| Paya Saman Pars Construction Company | 0.99742 | 2 |

The results of the data analysis indicate that Iran Housing and Urban Development Company ranked first with an efficiency score of 0.99838. This result suggests that the company has achieved a high level of efficiency through optimal resource allocation, effective utilization of technologies, and implementation of appropriate strategies in green supply chain management. The company likely performed well in areas such as construction waste management, energy consumption reduction, use of green and sustainable materials, and the adoption of innovative green logistics systems.

## 5. Conclusion

In today's world, as supply chains grow more complex and the importance of sustainability across economic, environmental, and social dimensions increases, selecting suitable suppliers has become a major concern for organizations. This study aimed to evaluate and rank sustainable third- and fourth-party logistics service providers by using a combination of multi-criteria decision-making (MCDM) approaches to systematize, rationalize, and multi-dimensionalize the decision-making process.

In the first step, evaluation indicators in the three main dimensions of sustainability—economic, environmental, and social—were identified and screened using expert opinions and the fuzzy Delphi method. Next, the FAHP method was used to determine the weights and relative importance of these indicators, incorporating the perspectives of managers and specialists into the weighting process.

Given that DEA is one of the most powerful tools for assessing the relative efficiency of homogeneous units, the cross-efficiency DEA model was used in this study to evaluate the performance of the five selected logistics service providers, accounting for undesirable outputs such as pollutant emissions. To avoid issues such as excessive identification of efficient units in classical DEA models, weight restrictions based on expert input were added, resulting in the development of an optimized model (Model 4) with 11 weight constraints. This approach improved the model's discriminative power and enhanced the final ranking of the suppliers.

The results of this study revealed that certain indicators—such as on-time delivery, transportation cost, energy consumption, and customer satisfaction—held the highest weights and importance in the evaluation process. Additionally, the final evaluation using the optimized DEA model showed significant differences in sustainable efficiency among the companies, with some performing weaker—particularly in environmental indicators.

Overall, the findings suggest that combining the FAHP method with DEA through a cross-efficiency approach and weight restrictions can provide a precise, reliable, and practical tool for evaluating sustainable suppliers. This framework can assist senior managers and decision-makers in making evidence-based, multi-dimensional, and scientifically defendable choices, while also identifying strategies for improving the performance of current suppliers.

## References

[1] Karimi, Jamshidi, & Bakhsham. (2023). Identification of Drivers and Indicators in Green Supply Chain Management Based on the Internet of Things. *Industrial Management Studies*, 21(69), 129–160.

[2] Farahabadi, Heydarpour, & Farzaneh. (2022). The Impact of Environmental Orientation on Financial Performance with Emphasis on the Effects of Green Supplier Management and Relational Capital. Judgment and Decision Making in Accounting, 1(1), 67–90.

[3] Hosseinzadeh Lotfi, F., Allahviranloo, T., Shafiee, M., & Saleh, H. (2023). Data Envelopment Analysis. In Supply Chain Performance Evaluation: Application of Data Envelopment Analysis (pp. 179-241). Cham: Springer International Publishing.

[4] Sanei, M., ROSTAMY, M. M., & Saleh, H. (2009). A new method for solving fuzzy DEA models. International journal of Industrial Mathematics, 1(4), 307-313

[5] Shafiee, M., Saleh, H., & Ziyari, R. (2022). Projects efficiency evaluation by data envelopment analysis and balanced scorecard. Journal of decisions and operations research, 6(Special Issue), 1-19.

[6] Saleh, H. I. L. D. A., Hosseinzadeh Lotfi, F., Rostmay-Malkhalifeh, M., & Shafiee, M. (2021). Provide a mathematical model for selecting suppliers in the supply chain based on profit efficiency calculations. Journal of New Researches in Mathematics, 7(32), 177-186.

[7] Saleh, H., Hosseinzadeh Lotfi, F., Toloie Eshlaghy, A., & Shafiee, M. (2011). A new two-stage DEA model for bank branch performance evaluation. In *3rd National Conference on Data Envelopment Analysis, Islamic Azad University of Firoozkooh*.

[8] Rahimi, Javanmard, Azizi, Najafi, & Seyed Esmaeil. (2021). Identification of Logistics Processes and Components and Determining Relationships among Them for the Establishment of Logistics Centers (Case Study: Arak Logistics Center). *Operations Management*, 1(2), 121–145.

[9] Zarindast, A., Majidi, S., & Pishvaee, M. S. (2018). A System Dynamics Approach for Capacity Planning within a Closed-Loop Supply Chain: A Case Study of the Lead-Acid Battery Industry. *Research in Production and Operations Management*, 8(2), 175–191.

[10] Ghaemi Asl, M. (2022). Modeling the Performance of Fourth-Party Logistics (4PL) Companies Using a Metaheuristic Algorithm Based on Backup Path Embedding and Delivery Time Guarantee in the Transportation Network. (Unpublished manuscript or academic thesis; exact journal/source not specified).

[11] Sarkis, J. (Ed.). (2006). Greening the Supply Chain. Springer.

[12] Hashemi, S. Khalil, & Eskandari. (2022). Investigating the Relationship Between Green Human Resource Management and Environmental Collaborations with the Moderating Role of Internal Green Supply Chain Management among Employees of Zamzam Iran Company in Tabriz. Green Management Quarterly, 2(1), 1–16.

[13] Chiniforoush, & Sheykhzadeh. (2010). The Relationship Between Organizational Performance and Green Supply Chain in the National Petrochemical Industry. *Exploration and* Production, (69), 26–33.

[14] Shafiei, Morteza & Tarmast, Pegah. (2014). The Impact of Green Supply Chain Management Processes on Competitive Advantage and Organizational Performance: Case Study of SAPCO. Quantitative Studies in Management, 5(2).

[15] Tariyan, Zandhasami, Hessam, & Khamseh. (2022). Explaining the Key Factors Affecting the Implementation of Green Supply Chain Management in the Construction Industry Using Meta-Synthesis Approach. Industrial Management Studies, 67(20), 238–266.

[16] Zarei, Kajal, Moshayekhi-Nezamabadi, Elmira, & Zarei. (2024). Identification of

Key Factors and Success Model for Implementing Green Supply Chain Management in Iran's Construction Industry. Dynamic Management and Business Analytics, 9(3), 5–22.

[17] Jamasebi, Novin, Elfat, Laya, Amiri, Maghsoud, ... & Mirsaman. (2023). A Model for Evaluating and Selecting Sustainable Third-Party Logistics Providers in the Supply Chain Using a Hybrid Approach of Fuzzy AHP and COPRAS Technique (Case Study: Dairy Industry). Iranian Management Sciences Association Quarterly, 17(68), 45–74.

[18] Keramat, Bashir Khodaparasti, Ramin, Bagheri Ghareh Bagh, Houshmand, Asgarnajad Nouri, & Bagher. (2024). Investigating the Effect of Green Technology on Sustainable Performance Mediated by Smart Logistics and Moderated by Green Governance in Knowledge-Based Companies. Executive Management Research Journal, 16(32), 121–143.

[19] Hosseinzadeh Saljoughi, Farank, Pishgooee, & Hamidi. (2024). Fair Allocation of Fixed Costs in One- and Two-Stage Systems Using Data Envelopment Analysis. *Innovation Management and Operational Strategies*, 5(3), 348–367.